Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

JOHN F. KELLY, EDITOR

CONTENTS

Volume X. JULY, 1933. Number VII.

ANTI-FRICTION BEARING SYMPOSIUM 167

EQUIPMENT AND METHODS NECESSARY TO MAINTAIN ANTI-FRICTION BEARINGS APPLIED TO ROLL NECKS by John L. Young, Timken Roller Bearing Co., Pittsburgh, Pa. 168

EQUIPMENT AND METHODS USED TO PROTECT ANTI-FRICTION BEARINGS FROM SCALE, WATER, MILL DUST AND HEAT IN CONNECTION WITH ROLL TABLES, INGOT CARS, MIXERS, HOT METAL CARS AND CRANES—by S. R. Cox Jr., Hyatt Roller Bearing Company, Pittsburgh, Pa. 171

EQUIPMENT AND METHODS USED TO PROTECT ANTI-FRICTION BEARINGS FROM SCALE, WATER, MILL DUST AND HEAT IN CONNECTION WITH ROLL TABLES, INGOT CARS, MIXERS, HOT METAL CARS AND CRANES—by V. A. Menaglia, SKF Industries, Inc., Pittsburgh, Pa. 173

EQUIPMENT AND METHODS USED TO PROTECT ANTI-FRICTION BEARINGS FROM MILL DUST AND HEAT IN CONNECTION WITH LADLE CRANES, CHARGERS AND SOAKING PIT CRANES—by E. C. Gainsborg, Roller Bearing Company of America, Trenton, N. J. 175

ECONOMIES EFFECTED BY THE USE OF ANTI-FRICTION BEARINGS IN CONNECTION WITH MILL TYPE AND GENERAL PURPOSE MOTORS—by T. Barish, Marlin-Rockwell Corp., Jamestown, N. Y. 177

ECONOMIES EFFECTED BY THE USE OF ANTI-FRICTION BEARINGS IN CONNECTION WITH MILL TYPE AND GENERAL PURPOSE MOTORS—by H. F. Brenholts, Fafnir Bearing Company, Pittsburgh, Pa. 178

DISCUSSION — ANTI-FRICTION BEARING SYMPOSIUM — Discussion presented by F. D. Egan, T. Barish, R. R. Owen, J. L. Young, C. E. Bedell, J. W. Bates, V. A. Menaglia, H. A. Smith, H. S. Heichert, H. H. Wood and M. Reswick 180

RESULTS ACCOMPLISHED BY A PROGRESSIVE SISTER SOCIETY—by J. F. Kelly, Managing Director, A. I. & S. E. E. 183

SOME CONSIDERATIONS IN THE SELECTION OF CONTINUOUS MILL DRIVES—by A. F. Kenyon, General Engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. 184

DISCUSSION—SOME CONSIDERATIONS IN THE SELECTION OF CONTINUOUS MILL DRIVES—discussion presented by S. Lavine, A. F. Kenyon, F. E. Fairman, J. Farrington, D. I. Bohn, C. E. Bedell, S. G. Girard, W. E. Waldron, W. B. Shirk and G. E. Stoltz 189

STRUCTURAL CHANGES IN HYPO-EUTECTOID STEELS ON HEATING—by Sir H. C. H. Carpenter, F. R. S., and J. M. Robertson, D. Sc., London, England 192

ARC WELDING OF STAINLESS STEELS—by E. A. Hurme, Clark Controller Co., Cleveland, Ohio 193

ITEMS OF INTEREST 196

BLAST FURNACE STATISTICS 197

A. I. & S. E. E. CONVENTION AND IRON AND STEEL EXPOSITION II

THE FUTURE OF INDUSTRY UNDER THE NATIONAL RECOVERY ACT—by Geo. M. Verity, Chairman, American Rolling Mill Company III

INDEX TO ADVERTISERS IV

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Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy $1.00.

A. I. & S. E. E.

Convention and Iron and Steel Exposition

October 17-18-19, 1933

William Penn Hotel — **Pittsburgh, Pa.**

TENTATIVE TECHNICAL PROGRAM

Cold Mill Practices.

Anti-Friction Bearings.

Fundamentals of Open Hearth Design.

Electrical, Mechanical, Lubrication, Combustion Developments in the Iron and Steel Industry.

Improvements in Steel Plant Furnace Design.

Oil Fired Soaking Pits.

Pair and Pack Heating in Connection with Sheet and Tin Mill Furnaces.

Electric Furnaces for Annealing Strip, Sheet and Tin Plate.

Normalizing Furnaces in Connection with Sheet and Tin Mills.

Electric Welded Frameless Steel Houses.

Developments in Electric Welded Fabricated Rolled Steel Products.

Present Operating Status of Electric Welding in the Steel Industry.

Developments in Electrical Applications in Connection with Strip, Sheet and Tin Mills.

Rectification of Electrical Power in Connection with Cleaning Blast Furnace Gas.

Mechanical and Lubrication Problems in Connection with Reduction Gear Sets.

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Allegheny Steel Company, Brackenridge, Pa.

Visitors will see modern Strip, Sheet, and Tin Mills in operation.

IRON AND STEEL EXPOSITION

Latest Improvements in Combustion, Lubrication, Electrical, Mechanical and Safety Apparatus used in Iron and Steel Plants will be on display.

EDITORIAL

The Future of Industry Under The National Recovery Act

By GEO. M. VERITY,
Chairman, American Rolling Mill Co.

This is the Industrial Age and Industry, misrepresented and misunderstood as it so often is, represents the very foundation of American progress and prosperity.

Any program or policy that would tend to stifle, retard or in any way injure our industrial activity or our sound industrial progress would be so serious in its effect that we would have to reform our entire social, political and economic lives.

As compared to any such radical reorganization of our National activities our experiences during the past three years of depression would be like an oasis on the desert.

It is therefore not at all surprising that so many are seriously concerned about the new situation in which industry finds itself under the new Recovery Act.

Many are, however, wondering as to whether this will prove to be "emergency legislation," or whether at the end of the two year period it will have become so established that it will be continued under a reduced or an increased government supervision.

The fact that this particular enactment is given a life of only two years really means nothing, as new legislation can be written into law then just as it has been done now.

Public opinion will in the end determine whether government supervision, over any part of our business activities, shall be continued in any form or not, and public opinion will be the result of the impressions created as we go along, as to whether this experiment has proven to be helpful or harmful.

If both Business and Labor, and Government believe they can and should be helpful, then it is up to them to contribute that sort of co-operation and efficient effort that will make it work.

It should be clear to every one in the very beginning that no satisfactory solution of our industrial or commercial ills can ever be had through dictation, domination or coercion on the part of either government or of any mobilized effort that may come into life during the operation of the Act.

It is beyond the vision or ability of any human being to foretell what will follow this partial socialization of industry and a governmental supervision over practically all business, as Administrator Johnson of the Recovery Act predicts. It is so radically new and so far beyond all of our past conceptions that it represents a revolutionary experiment.

I feel, however, that we can assume that we will never go back to the old order of things; that we will find that this is simply the first chapter of a new book and that no one can as yet foretell the trend of the chapters or acts that are to follow.

We have had abundant proof that our industrial and commercial enterprises, working under free and destructive competitive conditions cannot satisfactorily control their activities, either in their own preservation or in the best interests of the nation.

Some sort of a control factor, not available in the past, would therefore seem to be an inevitable part of our future planning.

We must remember that the drastic new legislation recently enacted, taken as a whole, was not the result of our depression experiences alone; it was rather the direct result of all the factors which contributed to the depression; it was, in other words, just a natural result of the general drift of things, social, economic and political, during the past fifty years.

If that be true, the "present emergency" is not entirely responsible for the Recovery Act; it is rather the result of many deep-seated maladjustments that cannot be cured in a short two year period.

Over and above all of this, any gains made toward more stable, more prosperous, and happier conditions will be the result of management and men, the consumer and the public-at-large working together whole-heartedly in a true spirit of co-operation in the interest of all, in an effort to garner every possible gain, large or small, that can be made.

The most important single factor is the relation that will exist between those who must do the Nation's work—that is among men and management.

Every gain of the past thirty years in industrial relations and in working conditions, every satisfactory condition now existing must be preserved and improved upon if possible. If the best interests of all are to be served there should be a "moratorium" on every new effort that will disturb existing satisfactory relations, that will create discord, contention, disagreement, or that will develop a retarding influence of any kind, as no such gigantic task as has now been assigned to Government and Business can possibly succeed through other than united effort.

Where organized groups exist and are working satisfactorily they should be continued by government decree; likewise where happy relations have been created between men and management over long periods of time, they should have their status maintained through government direction under the protective Codes which must now be prepared and adopted.

Minimum wages and maximum hours of work are now to be agreed upon between each industrial

(Continued on page 196)

INDEX TO ADVERTISERS

A

The Alliance Machine Co. 207
Allis-Chalmers Mfg. Company 198

C

Crocker-Wheeler Electric Manufacturing Co. 202
Cutler-Hammer, Inc. ..... Cover 1

E

The Electric Controller & Mfg. Co. 204
Electric Service Supplies Co. 200

G

General Electric Company ..... Cover 4

H

Hyatt Roller Bearing Company 205

I

Ideal Commutator Dresser Co. 206
I-T-E Circuit Breaker Company ..... Cover 3

M

The Martindale Electric Co. 208
The Morgan Engineering Company 199

P

Pennsylvania Transformer Company 209
Poole Foundry & Machine Company 203

S

SKF Industries, Inc. 210
Stimple & Ward Company, Inc. 208

T

The Thompson Electric Co. 209
The Timken Roller Bearing Company 201
The Tool Steel Gear & Pinion Co. 206

W

Westinghouse Electric & Manufacturing Company ..... Cover 2

Anti-Friction Bearing Symposium

AUSPICES OF

The Special Committee on Bearings

OF THE

Association of Iron and Steel Electrical Engineers

WILLIAM PENN HOTEL, PITTSBURGH, PA. FEBRUARY 25, 1933

PAPERS PRESENTED

"EQUIPMENT AND METHODS NECESSARY TO MAINTAIN ANTI-FRICTION BEARINGS APPLIED TO ROLL NECKS" by John L. Young, Timken Roller Bearing Company, Pittsburgh, Pa.

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HELP YOUR INDUSTRY — SUGGEST NEW USES FOR STEEL

Equipment and Methods Necessary To Maintain Anti-Friction Bearings Applied To Roll Necks

By JOHN L. YOUNG,
Timken Roller Bearing Co.,
Pittsburgh, Pa.

Maintenance has always been an important subject to every mill, since the cost of maintenance is reflected in the cost per ton of product rolled. It is therefore quite natural that with the constantly increasing use of anti-friction bearings in mills, that the operating men should seek information on the equipment necessary to maintain anti-friction bearings as used on roll necks.

To make this discussion easier to follow, let us for a moment diverge to a review of the three designs of tapered roller bearings commonly used on roll necks. Figure 1 shows a standard two-row bearing consisting of a unit inner race or cone with two nests of rolls assembled as integral parts with this race, two outer races or cups, and a cup spacer which is supplied with the bearing to make up a completely adjusted bearing. The parts are all properly marked and should always be assembled in accordance with the markings.

Figure 2 shows a unit two-row adjustable-non-adjustable bearing now used successfully in a number of mills. In this design we have again a unit inner race or cone, two single outer races or cups and a cup spacer. In this case however, the bearing is supplied as an integral unit which does not require further assembly of parts by the user.

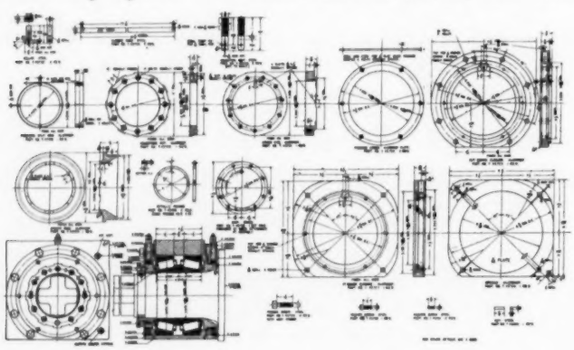

FIG. 1

Figure 3 shows the conventional four-row bearing extensively used in various rolling mills. This bearing consists of two inner races or cones, one double and two single outer races or cups, one cone spacer and two cup spacers. A number of these four-row bearings have been used without spacers. However, where a completely pre-adjusted unit is desired, spacers are used. In this case also the parts are properly marked and should be assembled in sequence according to the markings.

The basic principle of design of our tapered roller bearing allows adjustment. This feature also permits re-adjustment of the bearings after wear has occurred or may be used for the proper setting of the bearing clearance for the desired rolling condition. Bearings used on hot mills are set with different radial clearances than those used on cold mills

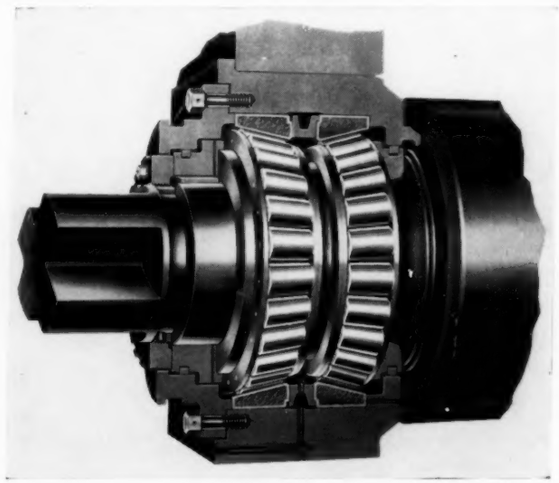

FIG. 2

and that this adjustment can be maintained for long periods has been definitely proven in practice. The average radial running clearance of these bearings on hot strip mills is a little under .001".

Figure 2 illustrates the mounting of the two-row adjustable-non-adjustable type of bearing. The same mounting is used for the other type of two-row bearing. To simplify handling and to speed up roll changes the bearing is mounted with a loose fit on the roll neck and clamped against the fillet and inboard closure ring. In this case the closures are of the piston ring type and as an additional precaution the face of the roll is grooved to permit a 180° extension of the chock to work in the groove and act as a water flinger. It will be noted that the inner and outer closure rings are designed with a projecting annular ring on the face adjacent to the inner race. These annular projections are larger in diameter than the adjacent bores in the chock and in the end cap. In this way there is a positive guarantee that when the clamping nut is taken off the roll and the chock is removed from the neck, the bearing and chock remain as a unified sealed assembly. Lubricant to the bearings is admitted between the two cups as shown. The entry in the case of grease lubricated bearings, should always be located at the bottom. A suitable vent should be provided near the top of the chock. The vent is not shown here but will be discussed later.

Figure 3 shows the mounting of the four-row type of bearing. Here again the bearing is mounted with a loose fit on the neck and properly clamped into place. The same principle of obtaining a unit sealed assembly is employed. The closures used are

of the clock spring type which will be discussed later. Here again a 180° water guard is used. The lubricant is admitted at the bottom of the chock. It is very important that two separate inlets be provided to allow the lubricant to enter the bearing through the holes provided in the cup spacers. A single vent hole is provided near the top of the chock.

The details of the clock spring closure mentioned above as well as the relative locations of the lubrication holes and air vents are clearly shown in Figure 1. The closure consists of a strip of metallic faced packing properly spliced at the ends with a flexible joint. This packing rides on the outside diameter of the inner and outer filler rings. Around this packing is used a thin steel band, the two ends of which are drilled with a small hole to permit a connection with a specially designed threaded adjusting bolt which fits into a collar. This collar is round in the body but upset at the bottom to keep it from turning when inserted between the closure plates. By tightening the two nuts on the adjusting bolt, the required fit of the packing on the filler ring is obtained. To protect the adjusting nuts it is recommended that threaded pipe caps be added to the end plates. It will be noted that the grease fitting is located at the bottom of the chock and leads to the opening between the two cups. The air vent consists of a plug located near the top of box. This plug is drilled two ways and the outlet is pointed down.

In addition to the clock spring and piston ring closures, rawhide closures have also been used successfully on small mill bearings. It is advisable to use these closures in pairs with one pointing in and the other pointing out.

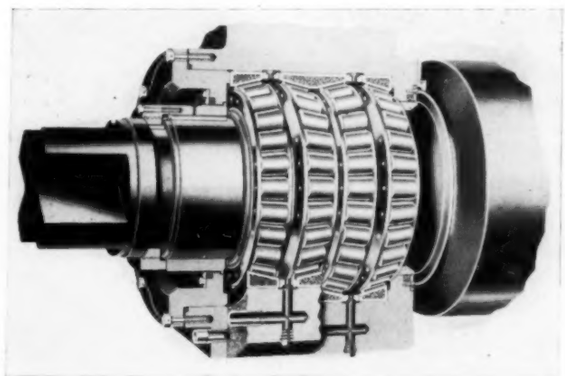

FIG. 3

Bakelite, Micarta, or composition rings are coming into prominent use where oil lubrication is used and with grease lubrication where water conditions are bad. These rings are usually located in a groove in the chock or end cap and rub against the polished face of the roll. Springs are used in back of the rings to assure a constant pressure on the face of the ring. In using these rings care must be taken of the clearances since it has been found that the composition rings swell in service.

Most of the mills have been keeping an accurate record of the tonnage rolled on each set of roll neck bearings. Others have not kept these records and eventually found themselves in the position of having to purchase replacement bearings without having an accurate record of what their cost per ton has been on the worn out bearings. By keeping an accurate record, proper charges for depreciation can be made and a fund established for the purchase of additional bearings.

TABLE 1

Record of Timken Bearings in Steel Mill: Tonnage and Operating Hours to Jan. 1st, 1933.

28″ Mill—July 1st to Dec. 31st, 1932.

Chock No.	Tons	Hours
28-1	93,716	2,965
28-2	31,114	1,166
28-3	114,352	3,547
28-4	132,118	4,068
28-5	81,450	2,578
28-6	147,741	4,518
28-7	113,938	3,446
28-8	180,509	4,378
28-9	175,073	5,860
28-10	162,622	5,094
28-11	213,299	6,466
28-12	120,851	3,812
28-13	40,366	1,425
28-14	64,020	2,137
28-15	64,481	2,153
28-16	83,259	2,508
28-17	40,045	1,326

Table 1 shows an abstract from the Timken Steel & Tube Co. on the performance of the bearings in their 28″ mill. It shows the tonnage rolled on each bearing and the number of hours each bearing has been in actual operation service. The list is complete to date, Jan. 1st, 1933.

It will be noted that each bearing chock carries a number. Each bearing and each roll is also properly numbered. When the roll shop assembles a bearing in a chock and a chock on a roll a record is made of the combination. The recorder on the mill when turning his records in after each shift shows on his sheet the serial number of chock and roll used in each mill. This information is taken daily from these reports and properly tabulated so that at a glance we can tell the number of tons rolled on each bearing and the number of hours the bearing has been in the mill. Many times the question has been asked as to just how mill bearings should be and how one knows when a bearing is properly lubricated. With the exception of only a few cases, all of our roll neck bearings have been grease lubricated. Originally we recommended that the bearing boxes be filled full for slow operating bearings and one-half to one-third full for higher operating speeds. Since then we have found that it is best to fill all

roll neck bearing chocks full until the grease begins to come out of the vent hole. This seems necessary for it has been found that with the boxes only half full there is a churning of the grease which increases the operating temperature. With the boxes full, the grease leaks out at the vent hole and closures until the bearings have properly channelled the grease. All churning is eliminated and the bearings run much cooler. During one of the recent meetings of this association the question was raised of the use of temperature indicating instruments in connection with anti-friction bearings in steel mills. The moving picture you have just seen showed a group of these instruments used to record temperatures of the back-up roll bearings of the Inland Hot Strip Mill.

There are three installations of instruments of this type in the Chicago district. So far these instruments have been manufactured and installed by two well-known companies. In all three cases the instruments used are of the recording type and there is one recorder for each mill stand. One type of instrument records by number. The other instrument records by color. In other words, there are four back-up roll bearings on each stand and in the case of the one first mentioned, each bearing is numbered from 1 to 4. The second system allows this use of 4 different colors.

In each case the recording is done automatically at pre-determined time intervals. These are, I believe, every 30 seconds.

Out of these three installations one of the instruments is equipped with a signal light, but all others are straight recorders without signal lights. Both types of recorders can be equipped with either a signal in the form of a light or a bell, but the objection to this tell-tale warning is that the operator will wait for the warning and will not watch the recorder and also might even forget to turn the instrument on when the mill is started.

In each case there is a thermo-couple or a pipe type iron constantan couple arranged in the bearing chock so that the unit comes in contact with the outer race of the roller bearing.

The charts of these recorders are good for one month of constant operation and they allow a variation in temperature of from zero to 350°F.

Our company has not deemed it necessary to recommend such a system but large roll neck bearings run into costs of several thousand dollars each and the loss of one of these large bearings would be more expensive than the original installation of the complete recording system for the entire mill, so that the value or cost of such a system may be justified purely from a standpoint of insurance. If the operator wants to add that extra ounce of precaution.

A number of mills have installed automatic grease lubrication systems for their anti-friction roll neck bearings. Some of these automatic lubricators have been connected and adjusted to deliver a definite quantity of grease at pre-determined intervals. If the closures on all bearings were equally tight and the speeds of the mills exactly the same, this quantity and time element could easily be controlled, but it seems that a manual control coupled to a pressure system is more logical for bearings of this sort.

In first installing the bearing chocks in the mill we recommend that they be filled until the grease comes out of the vent plug and especially in hot strip mills this condition should be checked periodically to be certain the chock is full of grease in order to check the entrance of any water or foreign material through the closures. The manual control will allow the operator to give the bearing the required amount to fill the chock properly and this, of course, can be determined by the sputtering of the grease and air from the vent plug. The Inland Hot Mill Back-up Roll bearings require 55-60 pounds in each chock to fill them. The work rolls require 12 pounds.

The question has been asked as to whether it is necessary to inspect the bearings periodically and just how this should be done. We strongly recommend that these inspections be made periodically, The periods of inspection depend entirely upon the size of the bearings in the mill and the work done on the mill. In one particular 4-high hot strip mill, 44 bearings were installed in January 1929 and were operated until the middle of 1932 having rolled over 400,000 gross tons before an inspection was made. All of the bearings inspected were found in perfect condition. In another case of a 4-high cold strip mill, the bearings were heavily loaded and ran continuously without inspection until bearing failures occurred. At that time the bearings were found in bad condition. Had these bearings been inspected periodically each could have been averted by elimination of the cause or if necessary by proper repair of any failed parts as each case warranted. Operating conditions are obviously the controlling factors and should establish the frequency of the periodic inspection. The service men of our company are available to give definite advice on this point.

Spare bearings should be carried for all mills but the quantity will depend upon the type of mill and the conditions. A greater portion of these spares are normally mounted in the chocks, properly greased, and ready for service. Those not in chocks should be covered with a light grease and stored in wooden lockers with hinged lids so that they can easily be lifted out with a crane.

It is advisable to assign the maintenance of the bearings to one department, preferably to the man in charge of the roll shop where a central roll shop is available. When a bearing and chock assembly is removed from the roll neck for bearing inspection it is advisable to first place the entire chock in a shallow pan where the cover plate is removed and a large part of the grease is taken from the bearing by scraping.

As each part of the bearing or the entire bearing is removed from the chock, such parts are carried by a crane to a cylindrical tank of sufficient size in which there is a solution of washing compound agitated by live steam. As soon as the bearing is removed from this bath it should be wiped and greased to prevent rusting and reassembled in the chock or placed in a locker.

Several suitable solutions for washing roll neck bearings when they are inspected are as follows—

1. A hot water solution of tri-sodium phosphate using three to four ounces of the chemical to one gallon of water.

2. A product sold under the trade name of "Metso". This is slightly higher in price than tri-sodium

phosphate but it is only necessary to use from one to one and a half ounces per gallon of hot water.

3. "Oakite" has also been used successfully.

4. In cases where the above solutions do not clean the bearings properly, which will happen only where the bearings are exceptionally dirty, an ounce of caustic soda (lye) may be added to each gallon of water.

Another question raised is the time necessary to change bearings from one neck to another. You have just seen the moving picture of the change of work roll bearings from neck to neck and the change of the back-up roll bearings at Inland Steel and can get an idea of the simplicity of the act. I should say that the average time necessary to change a work-roll bearing is from 6 to 8 minutes and for these large back-up roll bearings from 8 to 15 minutes by a trained crew.

When changing bearings on rod mill rolls where the bearings are tight on the necks there is a greater delay due to the fact that the bearings must be pulled off the necks. This condition of tight bearings exists only on the high speed stands, but here again a trained crew with the necessary equipment can change bearings in a relatively short time.

It is only a few years ago that the mill operators were wondering how far anti-friction bearings would progress in the steel industry and whether or not they would be justifiable and on what type of mills or other applications would they be practicable. It seems logical to assume even at this early date that the roller bearings have solved not all but a goodly portion of the roll neck bearing problems and with the knowledge we now have from actual experience and with the rapidly increased understanding of the mill men of the methods of handling and maintaining anti-friction bearings, the roller bearing has found a place for itself and it shall continue in its place.

Equipment and Methods Used To Protect Anti-Friction Bearings From Scale, Water, Mill Dust and Heat In Connection With Roll Tables, Ingot Cars, Mixers, Hot Metal Cars and Cranes

By S. R. COX, JR.,
Hyatt Roller Bearing Company,
Pittsburgh, Pa.

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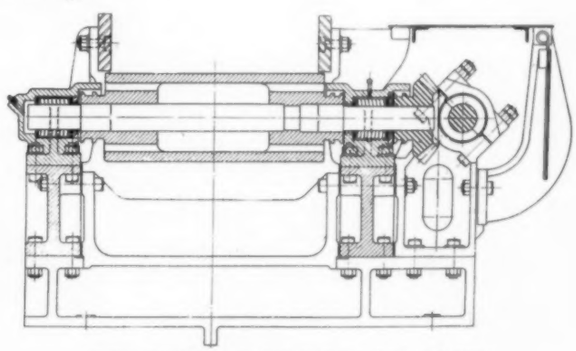
In the application of anti-friction bearings to various types of steel mill equipment, it is absolutely necessary that the intrusion of scale, water, dust, and other foreign matter be prevented. The deterioration of plain bearings is generally caused by abrasive action of foreign matter and consequent rapid wear of the bearing element and journals. With ordinary bearings, it is more difficult to properly enclose the bearing housing than is the case with anti-friction bearings.

In all anti-friction bearings, the rolling elements are hardened steel and being protected from foreign matter, do not wear, as is the case with plain bearings. Hence, the bearing housings can be made with close clearances around the shaft, and in very dusty applications, or where water is present, special types of seals can be used.

Felt seals in steel mill applications, have shown a tendency to collect dirt where it comes in contact with the shaft and, instead of acting as a seal, has a tendency to cut the shaft.

Our experience, extending over a number of years in the steel mill industry, indicates that maintaining a close clearance of the bearing housing around the shaft, when utilizing the common method of grease groove seal, prevents deterioration of the bearings.



Section through typical Hyatt bearing equipped mill table

FIG. 1

Bearings applied to the pallet wheels on a Dwight-Lloyd sintering machine, have been in successful operation for a number of years. This is a very difficult place due to flue dust, and the average life of anti-friction bearings in these machines, has been three years. They were lubricated once a week. The fact that anti-friction bearings prevent skidding of the wheels also reduces wheel replacements to a minimum.

A number of blast furnaces have been equipped

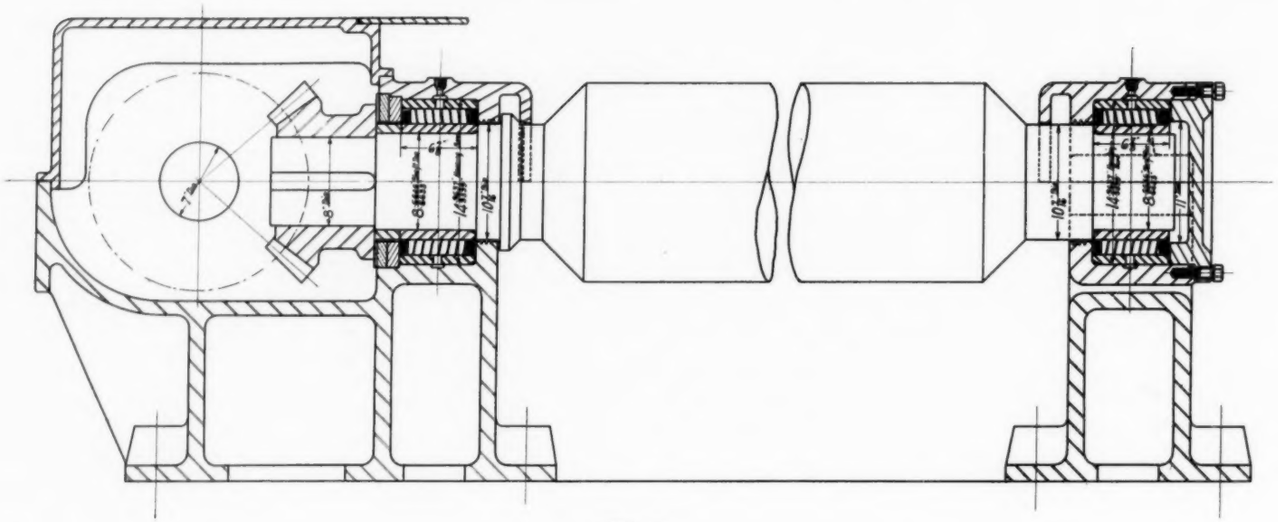


FIG. 2

with our bearings, including bull wheels, large and small bell levers, bell lever sheaves, skip cars, and skip hoists. Some of the bull wheel applications have been in operation for the past ten years. The lubrication periods are from three to six months.

Ore transfer cars, blast furnace larry cars, cinder ladle cars, and iron ladle cars have given years of successful operation on our bearings. A large majority of the ingot and charging cars in the steel industry operate on our bearings. Some of these cars have been in operation for the past fifteen years. Lubrication periods vary from three months to one year, depending on conditions.

The journal boxes on most of the cars previously mentioned, are of the outside box type and are entirely enclosed on the outside, protecting the bearings from dirt and hot metal spillage. The wheel side uses a grease groove seal. A large number of eight-wheel, double truck ingot cars, using inside Hyatt Bearing boxes, are in successful operation in a number of plants.

On high speed applications, such as hot and cold saws, where thin oil is used as a lubricant, extra precautions to exclude foreign matter must be taken. A labyrinth seal is recommended to retain the oil and exclude foreign matter. On other saw arbors, where a different type of lubricant is used, an increase in the number of grease grooves in the end plate has effectively sealed the bearings.

Soaking pit covers are subject to considerable heat and dirt. Due to the intense heat, our bearings operate without lubrication and use a simple plate seal. The fact that some of these installations have operated for fifteen years proves the effectiveness of this installation.

On some mill table installations, Figure 1, the bearing housings are subjected to considerable heat and dirt, also water and scale. The openings to the

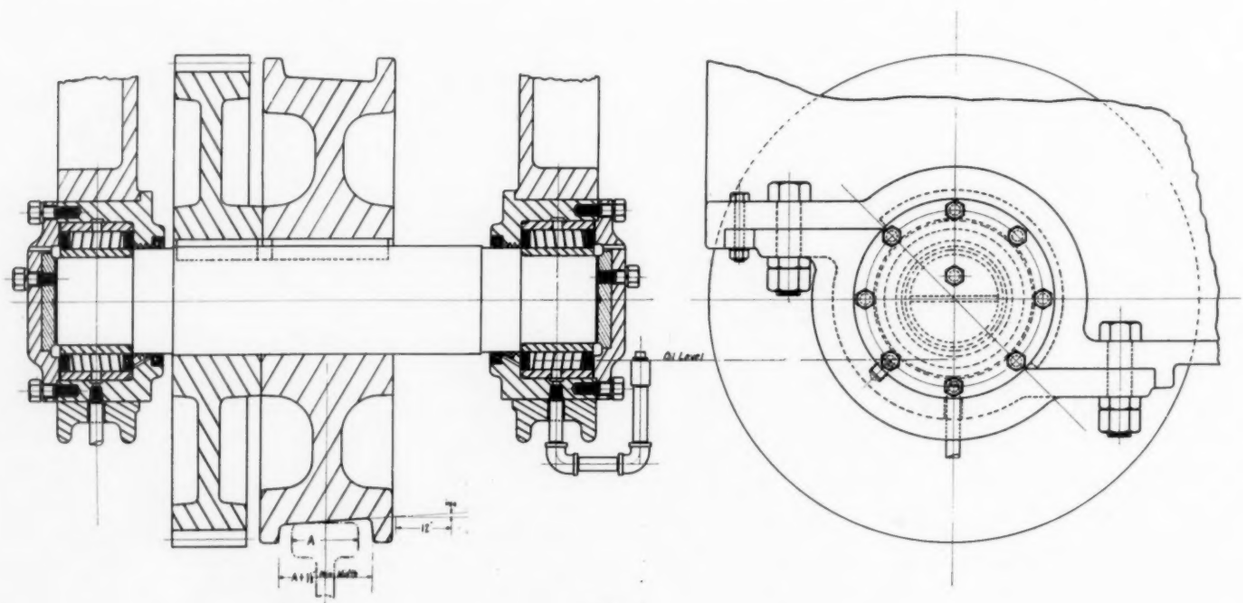


FIG. 3

bearing housings are protected by a shroud to deflect the water and scale, and a grease groove seal is used to retain lubricant and exclude foreign matter. This particular installation has been in service since 1918 on a 28" Structural Mill where over 1500 bearings are installed and labor conditions for maintenance are very poor. The total bearing replacements throughout this mill have not exceeded 5% of the original installation.

Figure 2 shows a section through the main manipulator table of a 44" Blooming Mill. This mill has rolled ingots weighing 73000 lbs. and has operated for the past two years without a bearing failure. The feed rollers and all table rollers, lineshaft, and drives on this mill operate on anti-friction bearings. Operating results on this blooming mill table, indicate that the shrouded housing with close clearance and grease grooves, has effectively sealed the bearings against roll scale.

A 34" Blooming Mill in another steel plant has operated successfully for the past eight years, with our bearings in the main tables. 70% of the bearings originally installed are still in operation.

Other blooming mill main table installations include two 40", one 44", one 35", and new tables on an old 38".

When it is considered that the average life of brasses on the necks of the main manipulator table rollers is approximately two months, the application of roller bearings on these tables will show a considerable saving in maintenance and delays will be reduced to a minimum.

The majority of the ladle cranes built during the past five years have been completely equipped with anti-friction bearings. The use of anti-friction bearings in the bridge track wheels prevents swinging of the ladle and allows very accurate spotting of the ladle over the ingot mould when teeming.

Figure 3 shows an anti-friction bearing mounting for a bridge track wheel. This design shows a leather seal and is designed to use 600 W or its equivalent. The filler pipe shown on the drawing can be used to maintain the oil level at the proper place, thus preventing the use of too much lubricant and the spillage attending same.

The leather seal should give a drip proof mounting and is especially valuable where the spillage of lubricant would ruin the product being handled.

On other installations, in the hands of a careful operator, the grease groove has proven effective as long as too much grease is not used.

This design also shows a tapered tread track wheel. Our experience has proven the value of this tapered tread wheel, and we recommend a minimum of 1½" clearance in the tread over the rail head. 2" clearance or more, depending on runway conditions, is desired where possible. This track wheel, where the tread is wide enough so that it does not rub on the side of the rail, not only eliminates thrust caused by a tight wheel trying to move the runway, but increases wheel and rail life and decreases power consumption.

Ladle cranes and other cranes in hot places are generally lubricated once a month, other cranes from three to six months, depending on conditions.

The ordinary type of grease groove seal which we have indicated on most of these applications, has proven its effectiveness in our application of bearings to steel mill equipment. There are many instances where additional seals are required, and it is only by taking each application into consideration that a definite recommendation for effectively sealing the bearings, can be decided upon.

Equipment and Methods Used To Protect Anti-Friction Bearings From Scale, Water, Mill Dust and Heat In Connection With Roll Tables, Ingot Cars, Mixers, Hot Metal Cars and Cranes

By V. A. MENAGLIA,
SKF Industries, Inc., Pittsburgh, Pa.

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The subject assigned to our company for discussion was the equipment and methods used to protect anti-friction bearings from scale, water, mill dust and heat in connection with roll tables, ingot cars, mixers and hot metal ladle cars.

The main considerations given to anti-friction bearings for application to the equipment under discussion is similar to practically all types of steel mill equipment employing ball and roller bearings. In general, it can be stated that these considerations are covered under three main headings.

1st — Selection of the proper bearing for the particular application under consideration.
2nd — The design of a proper housing for sealing the bearing.
3rd — Lubrication.

Taking up the first heading, namely, the proper selection of bearings, the following general statements will apply without any great deviation.

When the strength of machine parts are calculated, the maximum load is generally taken as the basis. The dimensions are so fixed that the stresses produced by the maximum load do not exceed certain limits determined by experience, and it is assumed that the parts will last for a practically unlimited time.

With ball or roller bearings, however, the conditions are different. Ball and roller bearings are rotating machine elements with a fatigue curve that, practically speaking, has no fatigue limit. As a rule,

however, they can be given dimensions that would enable them to last an unlimited time. Such dimensions would make the bearings too expensive. The calculations must, therefore, be based on a degree of durability suited to each particular case. Such durability, however, is not inversely proportional to the load, but is a cubic function of the load. Consequently, for applications where the magnitude and duration of the load are variable, the result is largely influenced by these variations and the maximum load can be taken as a basis for the calculation. In order, therefore, to enable a correct choice of bearing sizes to be made, it is necessary to take into consideration all the loads occurring and to fix an average.

To be able to give correct dimensions to the parts of material equipment, it accordingly suffices to know the maximum load, but when the parts concerned are roller bearings, it is necessary, also, to know how the load varies, or in other words, what the magnitude and duration of these loads are.

FIG. 1.—Illustration showing the date of inspection being lettered right on the car truck.

Bearing in mind the foregoing considerations, it will be appreciated why we bearing representatives desire this essential information. We are all willing to assist designers, through the facilities of our Engineering Departments, to make the proper selection. From our past experience on the life of bearings, based on their fatigue failures an accurate determination of the bearing life which is to be achieved, can be definitely determined. This is a vital point, since the proper economic design of any equipment should be based on the desired life under definite operating conditions.

Even with the above considerations carefully adhered to, it is not reasonable to expect the same uniform life from all bearings, since premature failures will always occur, due to the human elements in workmanship, housing design and lubrication.

FIG. 2.—200 Ton crane completely equipped with spherical and cylindrical roller bearings at all working points.

Taking up the second heading of housing design, we can generally state that it is one of the most important factors, assuming that the bearing manufacturer has selected and furnished the proper bearing. It is through the means of a proper housing design that effective methods can be taken to exclude the mill scale, dust, water etc. from the bearings in the equipment under discussion.

In the past, insufficient attention was given to this important item and, as a result, premature failures with their attendant shut downs could always be traced to faulty housing design. In many cases the only seals employed were of felt, which experience has shown to be entirely unsuitable for extreme conditions, such as we encounter in steel mill practice. It has been our experience that for this type of equipment suitable labyrinth seals and flingers are imperative.

By employing the labyrinth seals we remove the necessity of re-newing the worn out parts, such as felt seals, and the tortuous passage provided will

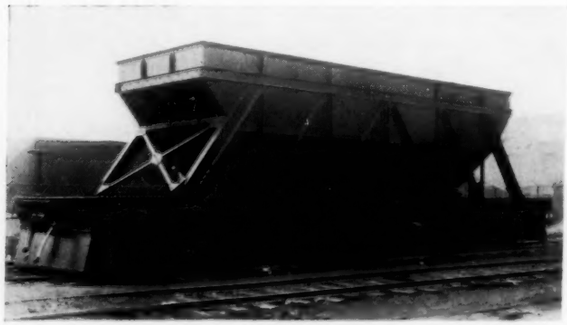

FIG. 3—Coke transfer car trucks equipped with SKF bearings.

exclude the entrance of all foreign matter. A rotating labyrinth flinger will also materially assist in throwing off excess water and, therefore, keep it from entering the bearing with attendant corrosion.

In the slides, which we will show later on, it will be our endeavor to show the evolution from the simple seals not suitable for steel mill equipment

on up through the better design of housings and seals, which is now generally accepted for such conditions which is encountered in the equipment under consideration.

With some of the more specific considerations, such as extreme heat conditions, it has been our experience that this can be taken care of by one of several methods. Generally, we can state that all bearing manufacturers desire to keep the bearing temperature below 300°F. This is due to the fact that, if a temperature much in excess of this is encountered, we reach the drawing temperature of the bearing steel. If this transpired, the difficulties, which will be encountered, are obvious, since the bearing will not have the proper hardness for carrying the loads involved. In order to keep down extreme temperature rises, it can be done by cooling the housing by circulating cold water through suitable passage ways in the main housing casting. The temperature can also be kept down by using a circulating oil system, which in turn is properly cooled before again circulating through the bearing.

The last, but not the least, important division of this problem, is the proper lubrication of the bearings. This, of course, is a more or less dangerous subject to cover within the limits of the time allotted to us. As a matter of fact it has been the subject of considerable discussion at the various meetings of this Association, and to date no agreed general conclusions have yet been brought forth.

Naturally, every industry thinks that its own problems of operation are the severest and under the most disadvantageous circumstances. We can assure you, however, that with respect to lubrication all industries are subject to practically the same problems. We all hope that in the very near future a mutual understanding will be effected between bearing manufacturers, the oil companies and the operating men with respect to certain basic principles regarding the lubrication of anti-friction bearings.

It is only fair to state that the attitude of some of the better oil companies, regarding this problem, are much appreciated by all of us, since they are endeavoring to clear up some of the blather previously peddled out regarding lubricants. It is our recommendation that a proper lubricant is to be selected upon the advice of the bearing representatives and the representatives of the more progressive oil companies. In the past, many of our difficulties were due to the fact that this problem of lubrication was left too much in the hands of Purchasing Agents. In other words, the lubricants were bought on a price basis, rather than with the understanding of their specifications and the conditions of operations which confronted the plant personnel.

The question as to whether oil or grease should be utilized is one not easily settled. Generally, it can be stated that for steel mill equipment grease lubrication would be preferable, because of its sealing qualities. It has been our experience that if proper greases are selected, the lubrication schedules can be materially improved. As an example, of what has been accomplished along this line, we refer to you the experience the railroads are obtaining with traction motors. It must be admitted that railway motors are in many cases operated under dirty conditions comparable to those encountered in steel mill practice. In the past they had approximately 65 to 80% plain bearing replacements per year. Some of the newer equipment placed in service on the Pennsylvania Railroad and New York, New Haven and Hartford have, due to proper housing design and proper lubrication, operated over 100,000 miles without the addition of any extra grease. This mileage is assumed to be approximately a year of service.

It is our recommendation that instead of adding additional grease from time to time, the bearing housing be completely flushed out and clean new grease of the proper quality and quantity be added to the bearing housing. This is the practice followed by the railroads and which we would like to see employed in steel mill practice.

Equipment and Methods Used To Protect Anti-Friction Bearings From Mill Dust and Heat In Connection With Ladle Cranes, Chargers and Soaking Pit Cranes

By E. C. GAINSBORG,
Roller Bearing Company of America,
Trenton, N. J.

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From the title of the subject up for discussion, it might be interpreted that it is limited to the design of Anti-friction Bearing Housing Enclosures best suited for use on Chargers, Ladle and Soaking Pit Cranes. From the standpoint of recognized Standard Anti-Friction Engineering Principles, it becomes necessary to set our starting point somewhat further back than the enclosure design.

For convenience, let us assume that fifty Anti-Friction Bearings of the same manufacture and size be installed in housings of like design, subjected to a load of the same intensity and operated at a corresponding R. P. M. also the lubricant and method of lubrication be maintained as uniformly as it is possible to do so.

If these fifty units are run continuously, day and night, until all the bearings show signs of fatigue of material, we would find that the majority of them had failed within a rather close period of time of each other; in other words, it can be stated that we have determined the average life value of these

bearings, measured in number of revolutions under a definite set of conditions.

Let us assume that we take fifty other bearings of a different size and design and if these be operated at the same load and speed as in the first case, in housings of a design different than used heretofore and that the lubricant and method of lubrication be modified, it can be expected that we will obtain an average life value which should be either longer or shorter than that established in case one.

This preamble leads to the statement that the usefulness or anticipated life of any Anti-Friction Bearing for any installation does not depend alone on the housing enclosure used, but must be considered jointly with two other factors, all three of which are basic. These factors are briefly stated as follows:

1st. Proper bearing selection as to type and size to best satisfy the prevailing conditions of load and speed.

2nd. Proper housing design to best satisfy the prevailing operating conditions to which the bearing shall be subjected.

3rd. Proper selection of lubricant and provision for its effective introduction.

To simplify our discussion, let us assume that, for a Charger, Ladle or Soaking Pit Crane application, the correct bearing as to type and size has been selected. What further consideration must be given so that we can receive the most from the bearings on the installation in question?

Our problem resolves itself in the necessity of properly satisfying the following design, operating and service conditions:

A. Introduction of lubricant, involves locations which are not readily accessible.

B. The housing and bearing shall be subjected to high degrees of temperature.

C. Provision for simplicity if bearings have to be replaced at some future date.

D. Enclosures which shall serve to retain the lubricant within the housing.

E. Enclosures which shall serve to prevent the entry of dust, dirt or foreign matter from without into the bearing housing.

Discussion:

A. Before giving any consideration as to the method of introducing the lubricant, it must be decided whether Grease or Oil should be used. While there is a general tendency to select grease, because it is believed that it can be better retained within the housing, the fact of the matter is that preference should be given to oil because it is possible to obtain a good grade of cylinder oil which is not compounded and consequently free from the fillers which are used in grease.

The lubricant, when used with an anti-friction bearing, is supposed to serve the purpose of coating a film of lubricant between the rubbing surfaces and that condition is not generally accomplished if grease be used.

If the grease is of a high consistency and holds its shape and form. the bearing will work out a channel or pathway thence no grease gets into and between the rubbing surfaces and consequently the lubricant ceases to function in the capacity for which it was selected.

If the grease is of a low consistency, due to surrounding temperature, it will have a tendency to flow freely and will resemble, in its flow, a cylinder oil but, on account of the fillers contained, will not be as efficient as a recognized good grade cylinder oil.

Conclusion on this may be drawn in favor of the use of oil in preference to grease.

B. We have stated that the lubricant serves to reduce the friction between the rubbing surfaces; on installations where high temperatures prevail, the lubricant should serve a second purpose and that is to aid in dissipating the heat away from the bearing and, to accomplish that end, it is necessary that the bearing chamber provide ample room for a substantial supply of oil—assuming that oil is used—and due to the circulation of the oil in the bearing housing, caused by the rotating of the bearing, if the oil chamber is ample, it will have the effect of reducing the bearing temperature.

Because a high grade bearing is expensive in comparison to the quantity of lubricant used, the answer is evident. Provide ample space in the bearing housing design.

C. On installations that are not readily accessible, a split type housing should always be used and, of course, it is desirable if the split is 180° apart and on a horizontal plane.

A split housing can be made so that it shall be absolutely oilproof on the surfaces where they join each other and further it can be so designed that strength will not be sacrificed.

The use of a split housing enables changing the bearings without having to remove the base of the housing, but only the caps, whereas the solid housing makes it necessary to remove the entire housing unit.

D. Many methods have been employed to retain the lubricant within the housing and as a substitute to accomplish that objective, grease has been often selected as a solution to the problem.

Seals which involve the use of felt, leather, cork or similar compositions have never proven satisfactory.

Assume that we start out with one of these compositions as a seal and when the unit warms up the diameters expand and added heat is introduced due to the rubbing of the seal on the shaft and eventually that results in charring and, at a subsequent date, the clearance between the seal and the shaft is increased and will permit the lubricant to seep out.

Long experience in Anti-Friction Bearing Engineering satisfies the statement that for a seal to be effective, you must resort to some mechanical design which rotates with the shaft and preferably it should be external and not internal.

A design which is in common use, but whose popularity is not extended because of its cost, consists of recessing a circular groove on the face of the end cover of the bearing housing. To the shaft is fastened, by means of set screws, a flinger which resembles a wheel hub with a flat flange on one end and on the face of this flange there is provided a lip which fits into the groove of the bearing housing recess. The flinger rotates with the shaft.

The inner section of the bearing housing is provided with a series of two or three oil grooves and the running clearance is maintained between the housing and the shaft.

The lubricant from within the housing has a tendency to flow along the shaft and dam up the oil holes, in its further path of travel it seeps between the face of the flinger and the face of the bearing housing and, due to centrifugal force, is pushed out, but gets no further than the lip on the flinger face and consequently there is no seepage. This design of enclosure is quite generally identified as a labyrinth type.

E. The flinger rotating on the shaft has the further effect of throwing off any dust, dirt or foreign matter which falls upon it and thereby prevents the entry of foreign substances into the bearing housing.

Economies Effected By The Use of Anti-Friction Bearings In Connection With Mill Type And General Purpose Motors

By T. BARISH,
Marlin-Rockwell Corp., Jamestown, N. Y.

The ball bearing industry has grown up with the thought that bearings must be manufactured without any internal looseness. At one time, the absence of any looseness whatsoever was considered an indication of quality.

Even today, when this practice has been greatly modified, ball bearings rarely have more than .001" total radial looseness. The average is about .0002", and it is not long ago that new bearings were returned to our factory as used or "worn out" because they had a slight perceptible shake.

In contrast with this practice the straight roller bearing has always been made with greater internal looseness. The average looseness is about .002" or approximately ten times the average ball bearing looseness. It is beyond the scope of this paper to consider the reasons for this difference but the fact remains that it exists. Note also that a wide variation exists within the group of roller bearings, and a few of the higher quality roller bearings approach the small internal clearance of the ball bearing.

Expansion of Inner Race

When a ball or roller bearing is pressed on a shaft the inner race or inner ring expands. The internal looseness of the bearing is reduced when the inner race expands. The bearing looseness becomes less by this total expansion at the outside of the inner race, or more exactly at the ball path.

The expansion of the inner race is not equal to the total press fit on the shaft but only a fraction of it. The pure theory indicates that this fraction equals the ratio of inside diameter to outside diameter for the ring. In ball bearings, this ratio varies from 65% to 90% approximately. So the looseness within the bearing should become less by about ¾ of the press fit on the shaft.

In practice allowance must be made for the condition of the shaft surface and bearing bore and for the straightness of these surfaces. Turned surfaces would first loose the tops of the fine ridges. They also tend to pound out more quickly. Likewise hollow shafts reduce the amount of inner race expansion.

Let us now examine the actual size of these expansions. In the past most ball bearings have been used with a lock nut tightly clamping the inner race against a shoulder and with almost no press fit on the shaft. The ideal was considered a line-to-line fit or slightly looser. Since there must be a tolerance on the shaft diameter and bearing bore for production the press fit will vary. The total tolerance for an average size bearing would be about .0012 and the fit of the inner race on the shaft would vary from .0007 tight to .0005 loose. The ball bearing manufacturers recommended tighter fits but these are what actually obtained in the field.

The maximum tightness of .0007 on a ground shaft would expand the inner race .0004 to .0006. Assuming that the bearing had only .0002 initial clearance, there resulted a positive squeezing of the balls between the inner and outer races. Each ball would be compressed by half the difference or .00015.

This positive squeeze or "Preload" can become quite serious if the press fit is increased, especially at high speed operation. The bearing develops a high pitched or "singing" noise. Heating occurs and sometimes early failure. Separator stresses increase as the balls never become loose enough to readjust their positions.

Much trouble has occurred in the last two years from this internal bearing "preload" produced by press fits on the shaft which expand the inner race enough to squeeze the balls (or rollers).

To correct this condition, make sure that there is enough internal looseness in the bearing initially to take care of the inner race expansion. It is vitally important for the bearing user and maker to cooperate towards this end. The man who installs the bearing should check every bearing after it is mounted on the shaft. There should still remain a slight internal shake or at least there should be no binding whatsoever.

The internal looseness of the average ball bearing has gradually increased during the past few years to take care of the inner race expansion, especially as press fits have increased. Nowadays practically any ball bearing purchased for replacement will have

.0004 or more total radial looseness. Even more is required as locknuts have been eliminated and press fits made larger.

Elimination of Locknuts

Locknuts are not necessary with ball bearings except to carry thrust loads, as has been proven by the successful use of ball bearings without locknuts on two of the most popular makes of general purpose motors for the last few years. No nuts are used even at higher speeds, 3600 RPM up to 2½" shafts and 1800 RPM up to 4" shafts.

It is desirable to eliminate locknuts where this can be conveniently done. Aside from additional cost, they increase the motor length and the overhang of the pulley or gear. The thread weakens the shaft at the point of maximum bending moment. Also the reduction in diameter at the thread makes necessary larger shaft diameters.

Roller bearings have been used without locknuts much more than ball bearings and much sooner. We see no reason whatsoever for this distinction. The action between the shaft and the inner race of a roller bearing is exactly the same as that of a ball bearing. The only cause for this distinction is the fact that the roller bearing has always had greater internal looseness and therefore automatically compensated for race expansion from greater press fits on the shaft. The distinction no longer exists now that ball bearings are made looser to suit. Ball bearings are used just as frequently without locknuts.

When ball or roller bearings are mounted on a shaft without a locknut, the fit must be made tight enough to prevent turning of the inner race on the shaft in operation. Very little tightness is normally required as it is only necessary to overcome the very low friction of the ball bearing. A rolling or kneading action occurs under very heavy loads, especially with thin races and then more press fit is required. In extreme cases, we must use a press fit on the shaft and a nut but normally a minimum press fit of .0002 is enough (.0001 on the smallest sizes.) The minimum shaft diameter becomes just .0002 larger than the maximum bearing bore or nominal bore (S.A.E. Standards).

The maximum press fit is then greater than the minimum by the total variations in shaft diameter and bearing bore which we can assume about .0012 normally or about .0014 total press. We must make the bearings loose enough to allow for the expansion that results. The bearing should then have .0010 initial internal looseness. This is frequently shaded to about .0008 because the maximum press fits do not occur often and even then the total squeeze of .0001 on each ball is not enough to be harmful.

When the press fit on the shaft is near the minimum, the inner race does not expand and the entire initial looseness remains in the bearing. A total looseness of .0008 is too small to be objectionable on most motors. There may be undesirable vibration or noise on some of the highest speed motors. It is then only necessary for the motor manufacturer to prearrange with the bearing supplier for less looseness and less tolerance on the shaft and bore. The additional expense is to be expected for higher speed applications and may be more than offset by the saving from taking out the locknut.

Economies Effected By The Use of Anti-Friction Bearings In Connection With Mill Type and General Purpose Motors

By H. F. BRENHOLTS,
Fafnir Bearing Co., Pittsburgh, Pa.

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Your Association, last April, completed twenty-six years of service to the Iron and Steel Industry. The first meeting was held here in Pittsburgh —attendance numbered twenty strong—the purpose of the meeting was—

To secure a mill motor which would stand up under the duties of making steel.

Practically speaking—the original purpose of the Association still exists as one of its major functions and may it never cease.

It is now history that the Association obtained immediate results which lead to the development of a direct current, distinctive, mill type motor.

The growth of electric motor installations were rapid and now aggregate over seven millions of horsepower. These motors range in size from a fraction to 10,000 horsepower. For anti-friction bearings the present main field ranges from 4 to 180 horsepower.

Reviewing briefly the situation leading up to the use of anti-friction bearings, we find sleeve bearings giving trouble, in certain types of installations. Rising maintenance costs with increased capital investment in spare parts soon lead the electrical department through an extensive study of motor construction, including bearing design.

It was not by sheer luck that in 1926, twenty-five electrical superintendents of your largest plants made independent surveys of their own causes of motor failures, which can be summarized for D. C. Motors, as follows:

41% Burnouts due to oil
6% Burnouts due to overheating
15% Burnouts due to moisture
21% Mechanical failures
17% Outside influence

The percentages on A. C. Motors were somewhat similar, especially the burnouts due to oil.

This indicates approximately half of the failures were traceable directly to bearings.

All mill type motors originally had split sleeve bearings, mounted in split housings. Oil is the lubricant for sleeve bearings, but has been found almost impossible to retain within the confines of mill motor housings and bearings. The persistence of oil in filling and escaping through any openings, and its tendency to vaporize thus saturating the armature and stator windings caused the greatest percentage of your failures. While a split bearing and housing has many advantages due to ease of dissembly, the difficulty of sealing foreign material out, and the oil in, awakened many individuals to the possibilities of anti-friction bearings.

The first changeover installations were made by adapting standard anti-friction bearings to existing motor housings. The motors selected were naturally those giving the most trouble, thus putting the anti-friction bearing "on the spot" immediately.

Here we should give the mill man our vote of thanks for his patience and perseverance, as he encountered many difficulties in adapting anti-friction bearings to the limiting confines of housings originally designed for sleeve bearings. Numerous bearings were overloaded, but in all cases the anti-friction bearing manufacturer supported the courage of his convictions, feeling he had the solution to most of the trouble, and together with the mill man, awaited the results. Some waited six months, others several years to be convinced, but the results were usually alike, motors were still in service which had previously, with sleeve bearings, been in and out for repairs several times during a similar period.

In justifying a replacement program the results spoke for themselves, and you were able to submit to your superiors the following facts:

Bearing failures were practically eliminated
Maintenance and Repair Costs were reduced.

This includes savings on such items as labor costs for inspection and oiling, costs for rewinding and replacing bearings and incidental costs for lubricant. As explained, leakage of oil caused the majority of failures with sleeve bearing motors. Grease is the satisfactory lubricant for anti-friction bearings and is easily retained within the confines of your mill motor housing, thereby eliminating this reason for motor failure.

Savings Resulted from Fewer Interruptions of Service

This is difficult to evaluate as it is dependent upon actual duty of the motor, but each of you can probably recall one of your costly plant shutdowns as a fitting example.

Reduced Capital Investment in Spare Motors and Parts

The increased life of motors and fewer failures permitted a smaller stock of spare parts.

Recommended anti-friction bearings are interchangeable in all their dimensions, thereby standardizing all shaft and motor housing fits. This makes for interchangeability of bearings with armatures and housing parts and simplifies stock control.

The trial of anti-friction bearings in addition to proving the above economies disclosed other valuable characteristics.

The life of any bearing is dependent upon clean lubricant. In the case of sleeve bearings it has been found almost impossible to keep out the foreign material which causes wear to both shaft and bearings.

Anti-friction bearings, because of their design requiring very small running clearances are and can be properly sealed against entry of foreign materials. Wear is extremely small and occurs only within the anti-friction bearing. Immediate replacement of worn bearing can return the motor to its original operating condition.

The anti-friction bearing using grease lubrication requires infrequent attention and therefore is ideally suited for motors located in inaccessible places. Inas much as the bearing and its closure is solid and symmetrical, any motor may be inverted for a ceiling mounting, or the drive can be taken off at any angle.

The inner races of all anti-friction bearings are shrunk or pressed on motor shaft thereby locating the armature, both radially and axially.

Vibration is minimized resulting in longer life for brushes, commutators, couplings and pinions.

This concludes briefly the history of the application of anti-friction bearings to mill motors, however, operating conditions change with the times, and mill motor manufacturers are now building and rating their motors for relatively high speeds, to supply the demand of the builders of steel mill equipment. This change in conditions must be met with the selection of the proper type of anti-friction bearing, as the motor manufacturer has now improved his design to help assure bearing performance.

In many instances, considerable thrust is imposed on the armature shaft from angle mounting of motor, trend toward helical gears, and other types of drives.

Let us consider the characteristics of bearings available—

Certain anti-friction bearings carry radial load only and separate bronze thrust collars are provided in the closure assembly. This design has but limited thrust capacity and frequent replacement of bronze thrust collars usually occurs when subjected to heavy thrust loading.

Other makes absorb thrust load against shoulders or flanges which are integral parts of the bearing. Their thrust capacity is usually but a small percentage of the radial rating. A third type carries the thrust load between two deep groove angular contact raceways and has a rated thrust capacity equal and in addition to its radial loading. The third type also has the advantage through its natural ability to withstand high speed service with a minimum increase in operating temperature, to answer that new demand of the steel machinery builders.

We all know that standardization of equipment is the greatest factor tending to minimize investment in spares, but too frequently we sacrifice this standardization for reasons that are not economically sound by carrying duplicate stock where one would suffice.

The third type mentioned is the deep groove

angular contact double row ball bearing. It is perfectly interchangeable with all makes, it has the radial capacity, the thrust capacity, operates at high speeds, and is now available in all sizes.

Therefore in the interests of economy you can also serve standardization by considering the bearing which will perform every duty and add further to the savings obtainable through use of the Standardized Mill Motors now anti-friction bearing equipped.

Discussion

F. D. Egan: Mr. Brenholts has explained the reason for changing motor bearings from sleeve to anti-friction, was due to oil leakage, followed by loss of mica between commutator bars of the D.C. motors and loss of the primary winding of induction motors.

One of the first motors we changed from sleeve to anti-friction bearings, was a 70 MC. mill type driving the bridge of a Foundry crane. This is a medium speed motor, has been operating very successfully since 1926. This motor was brought into the shop in 1931 and found in good condition, it was returned to the job and is still in operation.

The main reason for changing bearings from sleeve to anti-friction type, was to change from oil to grease lubrication and reduce armature changes. However present design machinery calls for speeds of 1500 RPM. on pumps, fans and machines of that type, and when driven by motors with horse power ratings from 100 to 200 HP. and larger and operation at this speed, have developed bearing trouble using grease lubrication, and if we are compelled to go back to oil lubrication we will defeat the reason for changing.

We have had trouble with several motors of this size and speed, flexibly coupled operating under ideal conditions yet developing high temperatures in the bearings. On two motors first one bearing will run hot and then another. We found the grease forcing out at the end of the bearings, and after cleaning the bearings and putting in new grease, the bearing will operate satisfactorily for a period of time. We lost one bearing on this location, yet they require too much attention. Bearing temperature as high as 180 deg. F. have been observed.

Is the cause of this heating due to high peripheral speed for this size of bearing using grease? I would like to hear an expression of opinion from the bearing manufacturers on this question, also if there is a limit in peripheral speed above which oil lubrication should be used.

T. Barish: I am glad Mr. Egan brought up the question of allowable operating temperatures because it is a very active one. When operating a motor with a bushing or plain bearing, the load is carried on an oil film. If the oil film becomes too thin it loses entirely its carrying capacity, and for that reason a temperature rise of 50° frequently means bearing failure, but that is not true in ball bearings. Even when run continuously at over 200° there is no direct harmful effect on the bearings. The loads are carried on a steel-to-steel surface and 200° F. temperature does not matter so far as the bearing capacity is concerned. This heat may indicate something rubbing or something else wrong, but it does not mean a bearing failure.

I know of some large pumps which include unnecessary circulating water cooling systems simply because the operator is accustomed to plain bearings and he must have the bearings cool enough so that he can keep his hand on them, so we have a water cooled operator's hand rather than a water cooled bearing.

In answer to the question of oil vs. grease, oil lubrication has certain advantages as follows: Almost any good oil will prove satisfactory for ball or roller bearings where variations in viscosity are not important. For that reason, on large bearings for expensive installations oil is frequently used just as a safety factor because you can rely on any operator to obtain a satisfactory oil. Also, he can drain the oil, clean the bearing and relubricate.

Greases on the other hand are subject to the one disadvantage that there are still quite a number of them that are not good, and care is required to avoid having some careless operator use poor grease. This danger may not be present very much in a steel mill where bearings receive some attention. Where greases can be used they need not be renewed as often, and they help the seals because they clog up the openings.

There are few high quality greases that can be used at very high speeds. The Yates American Machine Company used one particular grease for several years on 2" shafts up to 8,000 R. P. M., and materially reduced their failures to less than one-tenth of what they were before. However, there was only one particular grease that could be used in this service for the first few years. Fortunately, there are more available now.

In this connection, I would like to mention an unusual experience. We were testing grease at high speeds, and packed a grinder spindle full with grease to see what would happen. We kept a record of the temperature on a recording thermometer. Of course, these spindles heated. The temperature rose immediately to nearly the melting point of the grease. Then the curve was approximately flat for a period of one to several hours. Thereafter the temperature would drop suddenly to a very low point, as low as with oil lubrication, or even slightly lower. If the unit was stopped and started again the temperature did not rise as the first time. The conclusion is that if a ball bearing heats due to an excess of grease, allow it sufficient time to work its way through the grease before attempting to add more. To help it further, open the drain cock so the excess can work its way out.

R. R. Owen: Was that a roller or ball bearing, Mr. Egan?

F. D. Egan: Roller Bearing.

J. W. Bates: Mr. Farrington has just told me of a new lubricator for crane wheels he has heard about and I wonder if Mr. Young would care to tell us about it.

J. L. Young: Several months ago a meeting was

held in this hotel under the auspices of this Association at which time the question was raised as to the development of a device or a method of properly lubricating crane-wheel plain bearings. The subject at that time was "Spoilage of Finished Material from the Leakage of Oil from Overhead Travelling Cranes."

It so happened that during that meeting the question was asked by a member if anything had been brought out that would allow oil or grease to be held in such a way as to prevent the slushing back and forth in the journals that in turn would prevent spillage or leakage. Several days after that meeting I happened to run into a fellow who was developing such a device and as yet that device is not on the market.

I still think the roller bearing is the answer to crane-wheel and gear problems on overhead cranes but the steel mills still have a quantity of the old plain bearing equipment that they must live with for a time to come until they can justify the replacement of that equipment with modern anti-friction equipped cranes.

A short time after that interview I was talking to Mr. Farrington of the Wheeling Steel Corporation at Steubenville and as he was one of the men who was interested in the question, I explained the device to him.

At the present time plain bearings are lubricated by oil-soaked waste or by several methods of holding grease against the axle. The difficulty has arisen principally from the lack of constant pressure of the lubricating medium against the axle and as such requires constant attention to keep that medium in condition so that it will form a proper wiper or wick on the axle.

This device is a cylinder of felt arranged with spring inserts that will cause the cylinder to retain its cylindrical form even after being compressed and placed in the cellar under the axle. In that way the pressure is always maintained between the oiling device and the axle. This type of lubricator in the past has been unsuccessful due to the difficulty of maintaining that pressure and at the same time preventing the cylinder from rolling out from under the axle. This device has an anti-rolling arrangement consisting of cross-chains fixed to the springs that in turn create a tension at the movement of the cylinder and in that way prevents crawling. This is especially true on a cold morning or after the crane has been standing for some time and the oil has become frozen and the lubricator stuck to the shaft.

With this type of lubricator it is not necessary to fill the cellar with more oil than is necessary to be held in suspension by the felt and in that way leakage and spillage can be eliminated to a great extent.

The reason for bringing this to Mr. Farrington's attention as described previously was to answer his question as raised during that November meeting as I thought he would be interested in knowing of such a device.

C. E. Bedell: The remarks tonight seem to indicate that we have a big problem of co-operation between the mill builders, the builder of roller and ball bearings, the men who prepare the oil, and the men in the mills who take care of the bearings. I believe a method of co-operation among these agencies could be worked out with quite beneficial results to the general problem of anti-friction bearing applications.

J. W. Bates: The speaker who told us the story of the man who struck the M. C. B. bearings for twenty years, showed a picture of a car truck and in the picture there was a man looking at something in the journal. I would like to know what he was looking at in there.

V. A. Menaglia: The man shown in the photograph was lettering the date of inspection right on the truck. That brings up this question of what causes a bearing to fail. One of the first jobs I had was tending a pump, and if anybody has ever tended a pump he will realize what a strong tendency that sound will have to put one to sleep. In my case, I guess it was the smell of a burning motor that woke me up. As soon as I awakened I realized what had happened. I still had enough presence of mind to "Cover up my tracks" as far as the bearing was concerned. I got the oil and filled the bearing and when the master mechanic came around, nobody could explain why the motor burned up.

Coming back to this lubrication question, there is no doubt they still work that scheme on anti-friction bearings and some of us who had experience in getting our alibies ready in plenty of time, insisted when they inspected and added new lubricant that the date be carefully marked above the journal box. I suggest to steel mill operators that it would perhaps pay them to do the same thing. Most steel mills have regular maintenance men who go around and lubricate the bearings, but once in a while they slip and if some accurate data was in evidence, showing when a particular bearing was inspected and lubricated, it would perhaps help solve some of these problems a little easier.

Mr. Egan has raised the point about temperature rise. I want to more or less emphasize what Mr. Barish had to say on that point. Most companies recommended oil for the reason that greases varied too much and there were so few good greases on the market. With the advent of the higher speed motor and special types that some of the electrical manufacturers have brought out, such as fan cooled motors, it is sometimes difficult to hold oil in the bearing housings. With fan cooled type you have a different pressure on each side of bearing housing which allows oil to be sucked out into the windings. The only recourse is to turn to grease.

Mr. Barish brought out the point that if you use oil or grease, which is too light, you will have temperature rise due to churning action. We have found the same thing. In the past if we had temperature rise in the bearing motor, we thought the thing to do was to use a lighter grease. We went down to lighter and lighter grease but the temperature kept going up. We therefore reasoned that if a lighter lubricant didn't cool them, let us go to a stiffer grease and see what happens. In many cases you will be able with a heavier grease to lessen this temperature rise. The explanation is simple. If you use a stiff grease, the bearing will channel through it. We do not desire a lubricant to carry the load but to eliminate the small amount of friction between the rolling elements and the retainer. With a heavy grease you will throw it to one side.

It will cut into this channeled grease and there will be a certain amount of oil oozing out which will furnish enough lubricant for anti-friction bearings. If you have temperature rise, instead of going to lighter grease, go to heavier and in most cases your difficulties will be corrected.

H. A. Smith: We make both oils and greases; generally speaking of the highest quality, although we do have intermediate competitive grades. If anybody wishes to ask questions on either oil or grease, I will be glad to give them any information I have. Many of the troubles experienced, are probably due to poor quality of oil or grease, or incorrect type and consistency.

J. W. Bates: The troubles are probably often due not because the manufacturers do not make a better grease, but because the users do not buy a better grease.

H. S. Heichert: What provision should be made to preserve bearings in a plant that is not operating and is not expected to operate for some time? Is there any free acid or alkali in the oil or grease which might cause the bearings to deteriorate?

J. L. Young: The bearing housing should be packed as full of grease as possible and that grease should be of such an analysis as to prevent etching of the bearings. It of course is necessary to study each individual problem as quite a few bearings are lubricated with oil and it is more of a problem to pack those oil lubricated bearings satisfactorily to prevent rust during the idle periods. There is also a question of water that may have collected in the bearing housing and if that water is left in suspension or in such a position as to come in contact with any part of the bearing, rust may be expected so that the best plan for absolute protection would be to drain and flush each bearing and after flushing add grease in such a quantity as to thoroughly cover the bearing.

T. Barish: In answer to the question of how to take care of a plant that is shut down for a considerable period, there is a simple solution for the ball bearings, use petrolatum. This is a pure mineral and will, therefore, have no bad effects on the bearings. It is inexpensive. The best procedure would be to pack the bearings full of petrolatum, and perhaps rotate each shaft a few revolutions.

The petrolatum will melt at 130°. That is why it is not used more for lubrication, but it still remains a good slushing compound. Afterwards when it melts it will be absorbed by the oil or grease regularly used in the bearings.

H. A. Smith: We have done quite a lot of work, along with the ball bearing manufacturers, on greases that are used in their stock bearings, that is, bearings stored on shelves for months or years, or bearings that are put in a motor or machine where the machine or motor may stand in a warehouse for a long period of time. Most of the greases of the ordinary quality will separate slightly, which may be explained by the fact that they are all mechanical mixtures of a soap and mineral oil. The soap is a saponified chemical mixture of an alkali (usually soda or lime), fixed oil (animal, vegetable, or fish oil) and some moisture, the whole acting as a carrying medium, or sponge, to hold the mineral oil. Temperature changes of the grease tend to "sweat" the oil out of its "carrier".

We have brought out within the last three years some greases which were developed after going over the whole situation with the ball bearing manufacturers. These greases have given exceptionally fine results in both storage and active service, the former being like that where you pack the bearing with grease and leave it in a warehouse where in the winter the temperature may go below zero, and in summer go up to 110 or 120 degrees. They are pure soda soap greases with extremely short fiber, and are much more resistant to separation, oxidation and other detrimental changes, than any other greases we have tested in our research work.

Generally speaking, I agree that petrolatum is the lubricant to use where you will occasionally slush the bearing and leave it. Many anti-friction bearing manufacturers slush their products with petrolatum, as it is a pure mineral oil which is solid below about 130°F. and which will readily mix with the oil or grease used in the bearing when it is put into operation.

As to filling the housing with a grease; if that is done, I would say you should use the highest grade grease you can get. Frequently, when a bearing is packed with ordinary greases, the oil oozes out leaving the soap which will prevent proper rolling motion and result in practically immediate failure of the bearing.

F. D. Egan: In the case of cranes in an idle department, with an indefinite starting time, should the anti-friction bearings be washed out periodically or left stand after being slushed, and what grade of grease should be used for this application?

H. A. Smith: If the grease has been in there for some time, it would be good practice to clean them out. After the grease has been churned around it aerates; in other words, the grease mixes with the air and the air, being composed partly of oxygen, will tend to oxidize the fixed oil in the grease leaving an acid content which will etch polished steel. The one cleaning should be sufficient for a long period if the lubricant used for repacking the bearing is of high quality and resists separation. A petrolatum, which is a straight petroleum product, would be particularly suitable for this service.

F. D. Egan: If the crane has never operated and will not run for a long period, what is recommended as good practice?

H. A. Smith: The best procedure would be to remove the bearing, clean it and fill it with a high quality grease or (preferably) a petrolatum. If the bearing cannot be disassembled, economically, it would be advisable to fill the housing, say with a petrolatum, run it enough to force out most of the old grease and refill the housing (with petrolatum) for the long idle period.

H. H. Wood: I have a suggestion which may aid Mr. Egan in overcoming his difficulties with overheated bearings on motors. In his paper Mr. Young refers to the air vent which we incorporate in our roll neck bearing mounting. We got the idea of venting these chocks from an Electrical Superintendent who for several years has used air vents on anti-friction bearings in cranes and motors. In the first place, the use of the vent makes it easier to grease the bearings because if the closures are tight and no vent is used, it is necessary to pump the

grease in against an air cushion. By using the air vent there is no back pressure and therefore the grease enters easily. In the second place if the bearing overheats due to an excess of lubricant, the air vent permits the excess grease to find its way out after which the bearing should assume its normal running temperature. Finally, the use of an air vent really makes for cleanliness because without it grease is usually forced in against an air cushion and this air expands when it heats up, forcing the grease out of the closures. This can't happen with the vent. On one of our mill installations which was supposed to to be vented I noticed that the bearing temperature was constantly rising and on examining the vent we found that the pipe plug had not been drilled. The mill was shut down, we unscrewed the pipe plug, and grease shot 20 feet across the floor. The mill was again started after the pipe plug had been drilled to form the air vent and the temperature of the bearing constantly dropped until it assumed its normal operating temperature and there was no further trouble with overheating on this bearing.

M. Reswick: In the selection of a grease lubricant for ball or roller bearings, the user should make sure that he gets a product of the proper composition suitable for the particular application in mind. For example, in the lubrication of the large roller bearings on the roll necks of a 4-high mill, where there is some liability of water getting into the bearings, the grease should be of a lime base, which is water repelling. It is also desirable to have the grease possess extreme pressure characteristics to stand up under abnormal loads. On the other hand, for motors subjected to high speeds and to abnormal temperatures, the grease should be of soda base and very carefully manufactured. In general, in the selection of a grease lubricant, the grease manufacturer should be consulted, and his recommendations confirmed by the manufacturer of the bearings.

Results Accomplished By A Progressive Sister Society

By J. F. KELLY
Managing Director of A. I. & S. E. E.

The American Welding Society, one of the leading and one of the most progressive National engineering societies in the United States, will soon be enjoying its fourteenth anniversary.

It started with a membership of about one hundred and has grown to over fifteen hundred members, many of them being the leading technical and practical welding authorities of the United States.

The American Welding Society is today, the fountain head of all welding activities and its specifications and codes are not only the recognized standards, but they represent the combined efforts of the welding engineering fraternity in this country.

For example, in the early days, a wide variety of nomenclature and definitions were in vogue. Welding experts did not talk the same language. To meet this need a committee was appointed to draw up standard nomenclature, definitions and symbols. Not only has the matter of the common language been successfully solved, but standard symbols enable the draftsman to specify clearly and concisely the type, location and size of welding to be used, thereby eliminating confusion and expense. Other standards developed by committees of this Society or its research department known as the American Bureau of Welding, include standard tests for welds, standards for arc welding apparatus, specifications for welding wire and gauges for measuring dimensions of welds.

Perhaps the growth of welding during the past few years has been, to a large extent, due to the maintenance of quality standards and procedure specifications. In this way it is possible to eliminate the doubt as to the quality of workmanship, and engineers have, in general, come to look upon welding with greater confidence.

In the matter of codes the Society has also taken a leading and active part. The first code issued by the American Society of Mechanical Engineers for pressure vessels included some very restrictive measures against welding. The Society through its research department carried out an exhaustive series of tests which furnished authentic data to back up the Society in its demands for a more lenient code which would be fair to welding.

These demands led to the appointment of suitable joint committees which, through research work and deliberations, have resulted in the providing of a new code which permits the use of welding to an extent considered impossible a few years ago by even the most enthusiastic welding engineer.

In the structural welding field the Society has taken the initiative and has issued a building code which has been adopted by over a hundred cities and municipalities. The values have been used in the design and erection of several hundred important welded structures.

The research work of the Society is conducted under the auspices of a separate board, known as the American Bureau of Welding. This board is also affiliated very closely with the National Research Council and has representation from some fifteen leading scientific and engineering organizations.

An outstanding report of the American Bureau of Welding was recently issued. It is the report of the Structural Steel Welding Committee. It is also indicative of co-operation on a wide scale. The pro-

gram as carried out and reported included the welding and testing of nearly 2,500 specimens.

The participants in the investigation included three steel mills, 39 fabricating shops, 61 welders, 18 inspectors and 24 testing laboratories. The work was distributed over the central and eastern portions of the United States. A Canadian laboratory provided pilot or preliminary information based on the testing of 342 specimens welded in three Canadian shops. About five years have been spent on entire investigation. This report, occupying more than 200 printed pages, is available.

Some of the aims of the Society may be briefly summarized as follows:

1. To collect and make available authentic and up-to-date information on welding, gas and electric arc cutting and to be recognized as the authoritative source of such information by manufacturers in the welding field, users of the process, engineering societies and legislative bodies.
2. To provide a means for the interchange of knowledge and experience to aid in the solution of the problems of the welding art—technical, ethical and commercial—through co-operative effort.
3. To be the agent of the industry in co-operative research on important technical problems, and to serve as a common spokesman of the industry in matters pertaining to its welfare.
4. To provide opportunities for social intercourse, and thus to promote a better understanding among manufacturers, users and scientists in the welding field, and to foster a spirit of co-operation for the common good.
5. To encourage the development of welding through improvements in present applications and expansion of its uses into new fields, and to develop technical and ethical standards for the welding industry.

The Steel Industry, as a whole, could, with profit, follow the work and activities of the American Welding Society. The Steel Industry, in its endeavor to find new uses, new markets, new outlets for Steel, should lend its moral as well as its financial support to the American Welding Society, which devotes three hundred and sixty-five days of each year to developments in welding. The results accomplished by this Society's activities will, in the future, pay a handsome dividend to the Steel Industry when taking into consideration that with the use of welding, fabricated rolled steel products have a potential market of twenty million tons of Steel annually.

The Welding Engineering Division of the Association of Iron & Steel Electrical Engineers will co-operate in the future with the American Welding Society to the fullest extent. A close co-operation between these two Societies will, without doubt, prove a distinct advantage to the Steel Industry in its campaign for new uses, new markets, new outlets for Steel.

The Association of Iron & Steel Electrical Engineers, composed of twenty-two hundred members, desires at this time to express its appreciation to the American Welding Society on its fourteen years of progressive and successful efforts toward solving the problems of welding, especially for its splendid work on behalf of the Iron and Steel Industry. Its past certainly assures a successful future.

Some Considerations In The Selection Of Continuous Mill Drives

By A. F. KENYON,
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Presented before the Pittsburgh District Section of the A. I. & S. E. E.

The selection of the electrical equipment for the most advantageous operation of any continuous rolling mill involves the solution of a great number and variety of engineering and economic problems. To mention only a few, there are required the calculation of power requirements and the selection of motor sizes; decision as to whether all of the stands shall be driven by one large motor, in groups by two or more motors, or by individual motors; decision as to whether the drives shall be constant speed synchronous or induction motors or adjustable speed direct current motors or adjustable speed A.C. sets; decision as to whether the motors shall run at the mill speed and be directly coupled to the mill, or shall run at higher speeds and be connected to the mill through reduction gearing; and determination of a great number of details concerning the characteristics of the machines, and the makeup and operation of the control equipment. Many of these subjects have already been discussed at length and need not be brought up again now. Rather it is

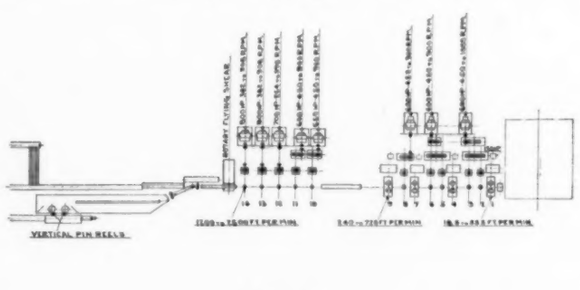


FIG. 1

the purpose of the present paper to describe a few of the more recent developments in electrical equip-

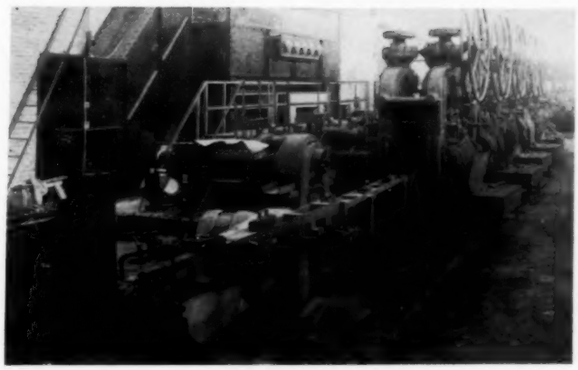


FIG. 2

ment and to discuss their applications to the drive of continuous and related types of mills.

Certain billet, bar, and rod mills are required to roll only a few specialized products, and with the range of products definitely known it is possible to design a simple mill arrangement for the economical production of these few specialized shapes. Economy in fixed charges and operating costs rather than flexibility to produce a wide range of sections is the primary consideration and is met by the group drive of the roll stands by one or two large constant speed motors. In the last few years, synchronous motors have been widely applied, and have proven eminently satisfactory, and afford advantages of unity or leading power factor, high efficiency, constant speed independent of load, and are often lower in cost than induction motors, especially for low speed 60 cycle ratings.

In contrast to the single-purpose specialized billet, bar, and rod mills, there are many mills which are required to roll small orders of widely different products. The wide range of product shapes, sizes, and grades of steel, necessitates adjustable speed operation, while to provide the utmost flexibility in the making up of rolling schedules, the speeds of the various stands must be independently variable, requiring individual motor drives for part or all of the stands. It is usual therefore for the modern strip or merchant bar mill to consist of perhaps fourteen stands in tandem or continuous arrangement and to be driven by as many as twelve adjustable speed motors. Figure 1 shows the layout of the new 10" strip mill at the Riverdale plant of the Acme Steel Company. With the exception of stands 2-3 and 5-6, the stands are individually motor driven, permitting individual adjustment of the roll speeds, and thus permitting wide variation in reductions. In the roughing part of the mill this maximum degree of flexibility is not so important, and also it is essential that the stands be located on as short centers as possible to conserve the temperature of the steel, so that these stands are best driven in pairs. Fig. 2 shows the five finishing stands of the mill, which are individually motor driven. In Fig. 2 note in the lower left corner the vertical pinch rolls and vibrator which deliver the strip to an apron conveyor when it is to be coiled, while at the left of the mill is shown the flying shear which can be moved into place when the strip is to be cut into lengths which can be handled on the hot bed. Illuminated dial ammeters on the wall of the control balcony enable the mill operators to note the load on each motor, and thus to adjust the mill drafts without assistance from the control desk operator.

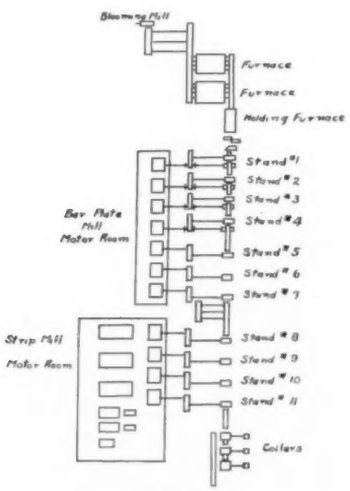
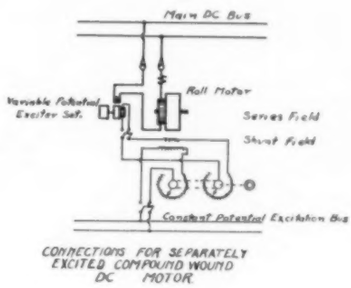


FIG. 3



CONNECTIONS FOR SEPARATELY EXCITED COMPOUND WOUND DC MOTOR.

FIG. 4

Fig. 3 shows the layout of the wide strip mill at the American Rolling Mill Company. Each roughing stand and its following vertical edger are driven by individual induction motors. The comparatively wide spacing of the large roughing mill stands and edgers affords ample room for the installation of the individual motor and gear drives. In case of accident to any mill stand or its drive, that mill stand may be shut down, and rolling continued by distributing the reduction among the other stands. Following the fourth pass the strip becomes long enough to be in two or more stands at one time, and the intermediate and finishing stands are driven by D.C. adjustable speed motors to permit control of the loops between stands. There are 4-3000 hp. motors driving the finishing stands, and 3-4000 kw. motor generator sets supplying 600 volt power.

Direct current adjustable speed motors have been used almost exclusively for these modern high speed mills, due to their satisfactory characteristics, and reasonable first cost.

One problem of which much has been written, and upon which there is a great difference of opinion among designing and operating engineers, is that concerning the need for motors of flat speed

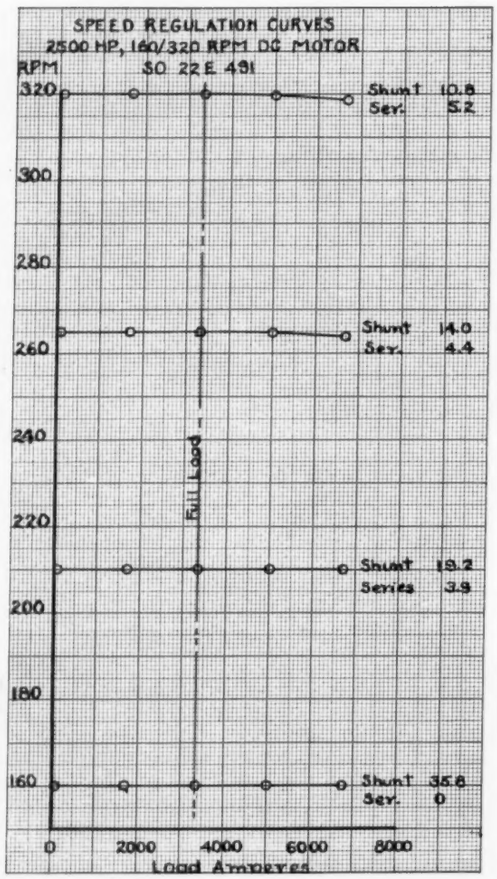


FIG. 5

regulation to drive the individual stands or groups of stands in a continuous mill. Certainly different mills with variations in stand arrangement, rolling speeds, and product shapes and sizes, require drives of different characteristics, and general comments applying to all mills cannot be made.

In medium and large capacities no great difficulty is experienced in the design and construction of direct current motors having inherent speed regulation of 2½% or less over a 2 to 1 speed range by shunt field control. By providing adjustment of the compounding series field excitation at several points in the speed range, the regulation may be considerably improved, and the stable speed range increased. The adjustment of the series field excitation may be accomplished by one or more knife switches connected to shunt a portion of the current. This method of adjustment has been successfully used on a number of installations, but is objectionable because of the limited number of steps of adjustment which can be provided, and because the operator must manually set the switches in the required position for the particular speed at which the motors are to operate.

These difficulties are overcome by indirectly compounding the motor with a series exciter, Fig. 4. A small exciter generator is excited by the main motor armature current, and hence develops a voltage proportional to the motor load. This voltage impressed on a separate field winding on the main motor thus produces the same effect as a strap series field winding. The proper value of series excitation for each point in the motor speed range is determined by test, and the shunt and series field rheostats proportioned so that they may be operated together to automatically provide the proper series excitation at all times to give flat speed regulation. The first such installation was made in 1925 on three motors driving a 10" merchant mill, and since that time our company has furnished about 70 equipments totalling nearly 100,000 hp.

Figure 5 shows the speed regulation curves for one of six 2500 hp., 160/320 rpm., 600 volt motors for a continuous strip mill, using series exciters.

The exciter sets are located in the basement, so that they may be easily connected in the main motor armature leads. An unusual method of supporting the heavy current aluminum bus connections are as follows. Insulation of alberene stone is held rigidly in steel frames which are easily made strong enough to resist stresses due to very large currents which may occur in case of a short circuit. In this case, with a total installation of 12,000 kw. of generator capacity and 18,000 hp. of D.C. motors, with possible future additions, the short circuit current may be several hundred thousand amperes, and to

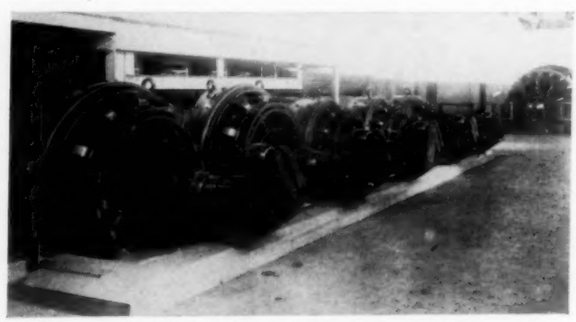


FIG. 6

withstand the resultant stresses the supports shown were found cheaper and stronger than any available porcelain supports.

For the great majority of mills the speed regulation which can be obtained with compound wound motors or motors with series exciters, is sufficiently low to assure satisfactory operation. However there are some mills which many operating engineers believe should have motors with speed regulation lower than can be obtained by equipment such as described above. Several types of regulator equipment have been used to automatically control the motor shunt field excitation and maintain a synchronized speed relation between the roll motors and some reference source.

Figure 6 shows five 500 hp. direct current motors driving the finishing stands of a 10" strip mill. The stands are spaced on 7'-0" centers, the maximum delivery speed is about 2600 feet per minute, and strip down to .025" thick is produced. It was thought that these conditions necessitated the maintenance of very close relation of speeds of these motors, and it was specified that the speed variation from no-load to full-load should not exceed ¼". This close control of the motor speeds was obtained by synchronous-differential regulators. A variable

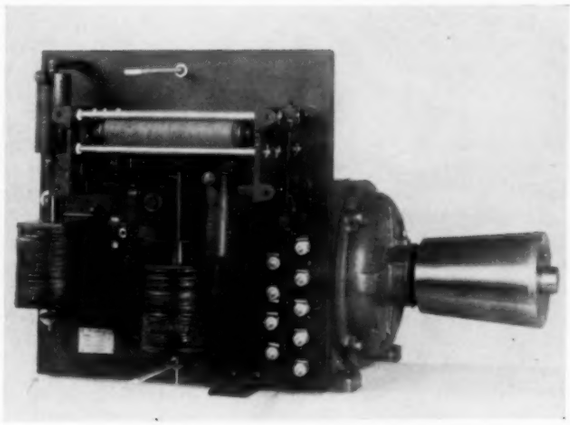


FIG. 7

ratio "Reeves" drive connects a small synchronous generator to each of the 500 hp. roll motors. These generators supply power to small synchronous motors, mounted on the switchboard panels and each driving one-half of a mechanical differential. The other halves of the differentials are driven by similar synchronous motors, all of which receive power from a master pilot generator. The middle part of the differential actuates relay contacts to regulate the roll motor excitation and hence control its speed. Any tendency of any motor to run faster or slower than the pre-determined speed causes a movement of the central part of the differential to increase or decrease the roll motor excitation sufficiently to restore the speed to the pre-determined value. Thus all of the motors are maintained in synchronized speed relation to the common master source, and hence to each other. The master pilot generator is driven by an adjustable speed motor so that the speed of the entire group of motors may be varied over a small range without disturbing the synchronized ratios of speeds. The ratios of the speeds of the several motors may be adjusted for different rolling schedules by changing the transmission ratios of the Reeves drives.

A more recently developed method of speed matching control utilizes a stack of carbon discs under varying pressure to regulate the excitation and thus control the speed of the mill motor. Because of its construction this device is known as a carbon pile regulator. Connected to each motor to be controlled is a variable ratio "Reeves" drive which drives the screw of a screw and nut mechanism. The nut is driven by a small synchronous motor, and the entire group of these small motors are supplied with power from a common generator and hence all run at the same speed. Any movement of the nut along the screw is translated through a system of levers to increase or decrease the pressure on the stack of carbon discs, thus decreasing or increasing the resistance and controlling the excitation and speed of the mill motor. With the mill motor driving the screw at the same speed that the pilot motor drives the nut, there will be no movement of the nut along the screw, but any tendency of the mill motor to run faster or slower will immediately result in relative movement in the proper direction to change the mill motor excitation and restore the balance of speeds. As in the case of the synchronous-differential regulators, the ratios of the speeds of the several motors may be adjusted by changing the position of the belts on the Reeves drives, and the speeds of all of the motors may be increased or decreased by controlling the speed of the master pilot generator which supplies power to all of the pilot motors on the carbon pile regulators. This newer type of equipment has the advantages of lower cost, greater simplicity, and smaller space requirement as the regulating equipment is all mounted at the mill motors without requiring any switchboard panel space. Figure 7 shows the construction of the carbon pile regulator.

Until a few years ago most mill designers endeavored as far as possible to use conventional and standardized machines for the drive of new mills. Now, however, in line with other progressive practices, they endeavor to devise the ideal arrangement and call upon equipment manufacturers to furnish the necessary special equipment. An interesting example of such special machines are two 800 hp. vertical motors, one 195/495 rpm. and the other 285/705 rpm., to drive vertical stands of a 10" continuous bar mill. In rolling small merchant bar sections, it is necessary to turn the axis of the bar with respect to the axis of the mill rolls 90° between passes. On early Belgian looping mills this was readily accomplished by the catcher handling the steel with tongs. As the continuous types of mills developed, the bar was twisted by means of properly shaped guides. Such guides are satisfactory for certain sections and at low operating speeds, but for the high operating speeds encountered on the last few passes of modern high speed continuous mills, mill operators felt that better operation would be secured by alternating vertical and horizontal roll stands. Several mills have been built with such vertical stands alternating with the horizontal stands, the vertical stands being driven through bevel gears by conventional horizontal motors. The rolling problem had been solved, but it was found difficult to keep water and scale from the bevel gearing, with resultant high maintenance, so on the most recent installation, the mill designers proposed the use of vertical rolls, pinions, and motor, and the arrangement shown was worked out in co-operation with the electrical manufacturer.

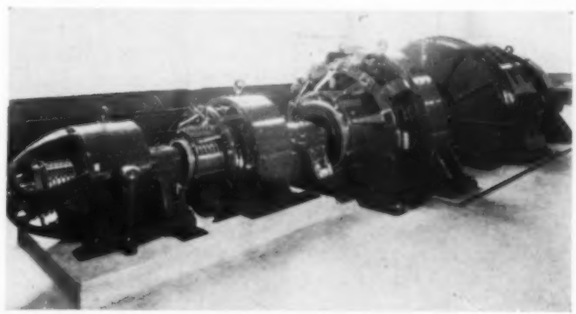


FIG. 8

With the use of direct current mill motors large installations of power conversion equipment are necessary. Synchronous motor generator sets have

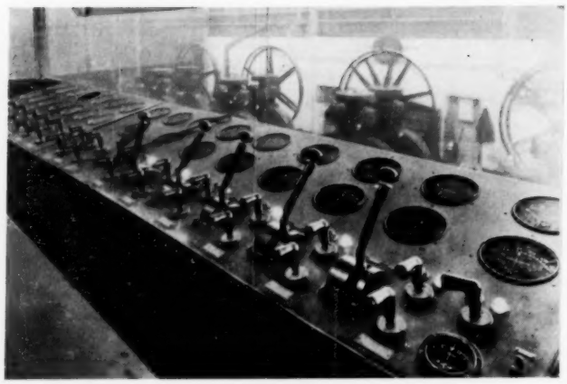


FIG. 9

been most widely used, and rotary converters have been installed in a few cases.

In selecting conversion equipment, the first calculation must naturally be to determine the total kilowatt capacity required, and next to decide what size units are to be used to make up this total. In moderate and large capacities, the cost of motor generators per kw. is practically the same, but the cost of switching equipment and floor space requirements are increased by the installation of several small sets, so that it is usually desirable to secure the necessary capacity in one or a few large sets. 600 volt generators can readily be built as large as 3000-3500 kw. and recent installations of 12,000-15,000 kw. total capacity have utilized three-unit sets of 5000 and 6000 kw. capacity. The larger machines usually have higher efficiency and when operating at nearly their full load the losses will naturally be lower than with the same capacity of smaller less efficient machines. However when a mill operates on a wide variety of schedules, some schedules, may require operation of only part of the mill motors, or the motors may be only partially loaded, so that only part of the total generating capacity is required. During such light load periods, operation of one of two small sets at nearly full load will be more efficient than the corresponding large single set operating at probably less than half load. It thus requires a careful analysis of the probable load conditions, together with equipment and building costs, efficiencies, etc. to determine the most economical number and size of sets to install.

As an example of a slightly unusual case may be mentioned the equipment for a 10″ strip mill driven by twelve motors totalling about 6000 hp. Calculations indicated a total required capacity of about 4000 kw. of 600 volt generators for the mill motors, in addition to which there was required about 400 kw. of 250 volt power for excitation and for auxiliaries. Power was being purchased at 12,000 volts, and for other mills in the plant this was being stepped down to 2300 volts in transformers at each mill motor room. The preliminary layout proposed the installation of a new step down transformer station, two 2000 kw., 600 volt sets for main power supply, and a 400 kw. set for excitation and auxiliary power supply. Later it was suggested that all of the generator capacity be combined in one large set to be driven by a 12,000 volt synchronous motor. This change made only a small increase in the cost of the M.G. set capacity, but saved the cost of the transformer substation, considerably reduced the size and cost of the motor room building, reduced the cost of the switching equipment, and permitted operation at about the same overall average economy, as the higher efficiency of the larger M.G. set and elimination of transformer losses was offset by operation at times when one 2000 kw. set would have carried the mill motor load, and also operation at times when only 250 volt power was required. Figure 8 shows the special 4400 kw. set, consisting of two 2000 kw., 600 volt generators, a 300 kw., 250 volt auxiliary generator, and 100 kw. exciter, all driven by a 6350 hp., 12,000 volt synchronous motor.

An important part of a mill drive installation consisting of power conversion apparatus and several mill motors, is the control equipment and particularly the meters, control switches, rheostats, etc. concentrated in the control pulpit for the normal operation of the mill. From this point the operator must be able to start, stop, reverse, and control the speeds of the mill motors, and in many cases also

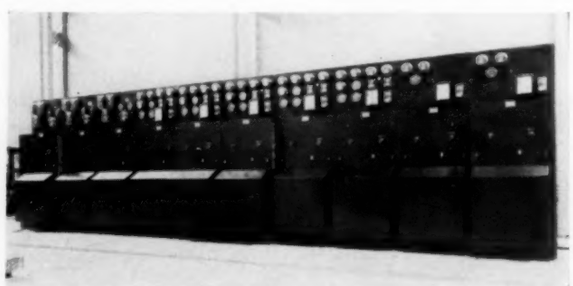


FIG. 10

control certain auxiliary machines such as mill tables, loopers, runout tables, flying shears and coilers. It is necessary therefore that the equipment be compactly arranged on the control desk so that all parts of the mill may be controlled from one position, and also that the desk size and arrangement be such that the operator can see all parts of the mill without assuming an uncomfortable position.

Figure 9 shows the control desk for the 10″ strip mill at the Acme Steel Company, other views of which were shown earlier. The desk was actually built in two sections, with the intention of locating one opposite the roughing part of the mill and a second opposite the finishing part of the mill. However the mill crew felt that they could make better speed adjustments of the roughing stand motors from the mill floor than to signal the operator in the pulpit, so that the fine speed adjusting rheostats are operated from handwheels on the mill housings, and the pulpit operator only starts and stops the roughing stand motors and makes approximate speed settings. He has complete control of the variable voltage supply generators and the five finishing stand motors and the runout table variable frequency M. G. set. Note that the front of the desk is made in removable sections so that the interior wiring is accessible for installation and maintenance. The lever handles operate the finishing stand motor vernier rheostats, located in the rear of the pulpit balcony, through shaft and bevel gearing.

As a concluding example of an interesting departure from conventional practice, may be shown Figure 10 showing an installation of truck mounted oil circuit breaker equipment to control 6600 volt circuits at the new Ambridge plant of the A. M. Byers Company. The novel feature of this installation is the 30" high super-structure on the hinged front panels of which are mounted the necessary meters and relays for the various types of circuits being controlled. The cost of this type of equipment is about the same as that of the truck structure without super-structure and with separate switchboard panels, but there is saved the cost of wiring and smaller floor space is required. The circuit breakers are standard type B-32, 1200 ampere, 15,000 volt, with an interrupting capacity of 350,000 kv-a.

This concludes a rather brief and rambling description of a number of recent developments of electrical equipment for continuous mill drives, and I hope that the various subjects were of interest and will provoke discussion of points which I may have overlooked or which were not made clear.

Discussion

Discussion presented by

S. Lavine, Engineer, Pittsburgh, Pa.

A. F. Kenyon, General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

F. E. Fairman, Engineer, General Electric Company, Pittsburgh, Pa.

J. Farrington, Electrical Supt., Wheeling Steel Corp., Steubenville, Ohio.

D. I. Bohn, Electrical Engineer, Aluminum Company of America, Pittsburgh, Pa..

C. E. Bedell, Electrical Engineer, Mesta Machine Company, Homestead, Pa.

S. G. Girard, Electrical Supt., Sharon Steel Hoop Company, Sharon, Pa.

W. E. Waldron, Electrical Dept., National Tube Company, McKeesport, Pa.

W. B. Shirk, Engineer, Pittsburgh, Pa.

G. E. Stoltz, Engineer, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

S. Lavine: Does the carbon pile heat up and change the resistance?

A. F. Kenyon: The resistance of the carbon pile may change due to changes in temperature, but the accuracy of speed control is not affected, as the regulator will merely assume a different position to provide the proper excitation to maintain the synchronized relation of speeds.

I also might add that, except on small motor ratings, the carbon pile does not directly handle the roll motor excitation current, but controls only the excitation of a small auxiliary exciter which in turn supplies the large motor excitation. In this manner the carbon pile is required to handle currents not more than an ampere.

F. E. Fairman: Let us assume that there will be a graphic instrument such as a recording voltmeter connected to the tachometer generator on the motor driving a stand the speed of which is to be regulated. Are we to understand that the curve drawn by such a meter will show a momentary dip at the time a piece enters this stand and that the regulator will act to over compensate for such a drop in speed? In other words, will the chart also show a ripple over what we shall term the normal speed line and then flatten out? Will the area described by the curve below the line on the initial bump be about equal to the area under the curve described when the regulator overcompensates in its initial regulating effort?

A. F. Kenyon: It is not possible to maintain an exactly straight speed curve with fluctuating load. As the steel enters the mill stand there is a momentary drop in speed, then the regulator responds to quickly return the speed, usually slightly overshooting and then settling to the desired value.

A member: How close can you come to speed regulation with that type of controller?

A. F. Kenyon: Such speed matching equipment will provide practically zero speed regulation under steady load conditions, as the equipment comprises elements which must rotate in synchronism. Of course after the load has increased from friction to full load it requires as much as one or two seconds to reach a stabilized condition.

J. Farrington: As regards regulation on our hot strip mill, we have had very little trouble in maintaining constant tension. When the mill is set up for a certain gauge the operator is able to maintain that gauge within commercial tolerance.

I do not know of anything else of interest except that we finish at 1200 speed a minute. I understand other mills have exceeded that.

A member: That picture showed heavy bus going down to the machine. I was wondering whether you excite that with the full current; also how you get the heavy bus into the machine?

A. F. Kenyon: The series exciter fields carry the full armature current of the 3000 HP. mill motors. Obviously the full bus section cannot be carried around the field of the small exciter generators, but this winding consists of only a half turn on each pole and two or more poles may be connected in parallel. Also the field winding is quite short, and the copper is a good heat conductor so that the heat generated in the field winding flows out into the large section bus, and the field temperature is kept at a safe value.

D. I. Bohn: I saw that particular installation and was very much interested in it. To what extent are such installations used by operators? You know what the experience has been with men in the mills.

A. F. Kenyon: The question of speed regulation is one upon which there is much difference of opinion among various designing and operating engineers. Some operating engineers insist that very low regulation is necessary and special speed regu-

lating equipment such as described in my paper has been furnished to meet such exacting specifications. Other engineers do not feel that such performance is a necessity, and are operating almost identical mills successfully without such special regulating equipment.

D. I. Bohn: Have they ever used a scheme where field is kept constant?

A. F. Kenyon: We have not made any installations where the field excitation is regulated to a constant value.

C. E. Bedell: I have been greatly interested in the remarks here this evening but since my experience has been mostly with the operating end of the game I prefer to speak from that standpoint. In making really new installations it is rather difficult to recognize the necessity of automatic regulation. We, therefore, often follow the procedure of including all the extra refinements that we think should be needed and then as actual operations give us experience we often eliminate a good many of these extras.

A. F. Kenyon: The motor shunt field switches are usually located in the operating pulpit, so that emergency operation in the reverse direction may be obtained by reversing the shunt field excitation by means of the double throw switches. The motors are usually provided with overspeed devices, and the control equipment includes field failure relays, so that the danger of accidentally opening the shunt field circuits is small. In some installations the shunt field control has been made magnetic controlled from push buttons or control switches on the control desk.

The coarse speed adjustment motor field rheostats are usually motor operated and hence may be located in any convenient place, usually in the motor room, where they are well protected and accessible for maintenance. The vernier rheostats are best hand operated from handwheels or lever handles on the control desk, and hence must be located close to the operating balcony. In various installations they have been located in the rear of the balcony behind the operator; and directly beneath the pulpit.

S. G. Girard: Somebody asked about meters. We do have a meter in the pulpit; also load curve of each motor on the outside. Opposite the verticals there is a meter showing the load and meters for the finishing mills, each on the front of the pulpit, so that the operator can see what load he has. Besides the operator being able to control his speed from the panel, we have a push button right on the housing so the roller can make fine adjustment without calling on the operator.

J. Farrington: We had meters in motor room and also set of meters in the operating pulpit in the mill and after the system was in operation three or four months, the rollers asked for meters to be put outside the pulpit near the stands and they gauge their draft on each stand by those meters, and when one gets out of order, they get right after us to repair them so we know they are actually using the meters.

A. F. Kenyon: On the older types of mills in which several stands were driven by each motor, meter indications did not mean a great deal in assisting the roller to properly proportion the work among the several stands. However with individual motor drive of each stand, the meters are of very real value in helping the roller to properly adjust the mill.

W. E. Waldron: We have the large illuminated dial Station Type Ammeters in the mill for the benefit of the rollers, who are governed somewhat by these instruments, especially when setting up the mill. As to speed regulation, I believe the motors are guaranteed to be within two per cent without speed regulating equipment other than a voltage regulator. Mr. Kenyon mentioned one-fourth of one percent. I was wondering if he knew whether the mill required such close regulation.

A. F. Kenyon: It is doubtful if extremely close speed regulation is required except in some very special cases.

W. E. Waldron: As far as I know, within 2% is what we have. We have never experienced any trouble with that regulation.

W. B. Shirk: Quite a number of gentlemen have raised the question as to the value of speed regulation required for a given type of mill. Instead of speaking of the speed regulation of the motors I prefer to think in terms of the speed variation obtained on the mill rolls due to changing load conditions. Considering speed variation on the mill rolls takes into account the performance of all associated electrical apparatus in order to obtain a satisfactory producing unit. The allowable speed variation on the mill rolls depends on the design of the mill and the ability of the mill operator to handle a large number of units in operation at one time so as to produce a satisfactory product. According to the rules of the A. I. E. E. speed regulation is the difference between the no load RPM. and full load RPM. divided by the full load RPM. Therefore a motor can be adjusted so that it has the same RPM. at full load as at no load and then you have zero percent speed regulation. However at some value of load between no load and full load the speed regulation may be as much as 5%. Due to the fact that the motors are not always operating at full load it is then up to the operator to estimate what the no load speed must be in order to obtain the correct rolling speed when using equipment with such characteristics. Our engineers when designing main roll drive motors and generators take as many variable out of the equipment as possible so that the mill operator can devote his attention to other problems. When we state that the speed regulation of the motor will not exceed 2% we mean that the difference between no load and full load RPM. will not exceed 2% for a change in load for any load from no load up to full load at any point over the entire speed range. A motor with such speed regulation will have practically a straight line "load-speed" curve. The generators supplying the motors are fully compensated and constant voltage is maintained on the bus. Therefore since constant voltage is maintained on the bus and the speed regulation of the motors does not exceed 2% for any load up to full load over the entire speed range the operator knows exactly how each motor will perform and no guess work is required in order to obtain the proper speed relation between adjacent stands.

C. E. Bedell: On the question of speed regula-

tion I have in mind a case where considerable thought was given to the question of very fine speed regulation on a continuous mill of 10 or 11 stands and it was thought that we would experience considerable difficulty if we did not have fine regulation. After the installation was made with only the nominal two or three percent motor speed regulation inherent in the motors we found that practically no difficulty was encountered and that the pulpit operator could even leave the mill to run for several minutes without attention.

F. E. Fairman: It has been mentioned that the speed regulation that has been discussed here tonight is supposed to give very close regulation in speed. In fact, from the general discussion one would infer that the claim is made that the regulation will be even less than one-fourth of one percent. I am wondering whether any manufacturer would recommend this scheme of regulation or any scheme of regulation supposed to give similar close results for a steel mill drive. Would not the customer rather have to demand such regulation and then the manufacturer reluctantly offer it, in practically every case? Of course, in asking such a question I am guided largely by my own personal feelings in the matter, but I am interested in learning whether they are corroborated elsewhere.

W. B. Shirk: Mr. Bedell mentioned that 2 percent speed regulation was 100% satisfactory. That is good speed regulation if 2% is the maximum speed variation obtained on the mill rolls under rolling conditions. The speed regulation guaranteed on a motor is the speed regulation obtained on the electrical manufacturers test floor with constant voltage applied to the motor terminals. If you supply constant voltage to the motor terminals and maintain the commutator and the brushes in the same condition as the electrical manufacturer had on their test floor you will obtain absolutely the same speed regulation as the electrical manufacturer obtained on their test floor. Therefore if constant voltage is maintained on the bus and the motors are kept in factory condition the speed variation on the mill rolls will not exceed the motor speed regulation guarantee.

J. Farrington: I was wondering if there are any mill superintendents in the room who have the regulating equipment described in the paper and if they will give us their opinion on how accurately this equipment actually does work.

G. E. Stoltz: It cannot be definitely stated that one method of speed control is necessarily better than another unless we have in mind a particular type of mill on which it is to be used. We would like to supplement the remarks made by Messrs. Shirk and Kenyon. If we assume a mill stand as driven by a direct current motor having 10% regulation, its speed with the stand empty will be virtually no load speed but the moment full load is imposed on the motor its speed will drop 10% until the pass is completed at which time it will return to its no load or friction load speed.

If you remember, on one of the curves shown by Mr. Kenyon, there were four speed regulation curves shown for the one motor. One of these curves represented the full field speed at various loads up to 200%; another its maximum weakened field speed at 320 R. P. M. from zero load to 200% load; and the other two curves represented speeds intermittent between these two extremes. These curves were plotted from speeds obtained at various loads while the motor was on our shop test floor. If we remember correctly, all of these speed points were on straight lines except on the two top speed curves where the speed of the motor dropped slightly as its load approached 200%. This is a very good performance for adjustable speed D.C. motors and these results are obtained somewhat as follows. The motor will have a series field which will cause its speed to drop as its load increases. After the speed regulation is obtained on the test floor this compound motor can be made to operate at virtually constant speed throughout its capacity by shunting the series field. It might be assumed that this is done at its full field speed and in this particular case the motor would then operate at 160 R. P. M. up to 200% of its load.

The shunt field can then be weakened to cause the motor to operate at some higher speed and as load is added it will probably be found that its speed will drop, and to cause the machine to again operate at a constant speed regardless of load it will be necessary to shunt more current from the series field. When motors of this type were first built several knife switches were placed on the frame so that the series field could be shunted and an increasing amount of current will be shunted from the series field as the shunt field is weakened. It was found, however, that this was not a particularly satisfactory method of adjusting the series field in practice and later machines were designed to have a separate exciter for the series field. It was then possible to place a field rheostat on the series exciter operated from the same shaft as the shunt field rheostat and adjustment in the series field current would then be made automatically as the shunt field rheostat was included. This is a very satisfactory arrangement for a large number of mills where fairly close regulation is desired.

As outlined by Mr. Shirk, there are other factors which may affect the regulation of the motors that this equipment does not control and that is a variance in the temperature of the machines, or voltage drop on the commutator as affected by the condition of the commutator; or the regulation of generators supplying the motors and voltage drop in the bus.

Regulating equipment can be added which will cause the motors to operate at fixed speed regardless of these outside conditions and to a certain extent independent of the inherent regulation of the motor itself. This may consist of a regulator as described by Mr. Kenyon and depends for its performance on holding a differential from rotating, one side of which is driven by a synchronous motor getting its power from a master set and the other side driven by a synchronous motor which is driven by the direct current motor to be regulated. As long as the correct speed is obtained these two synchronous motors will operate at the same speed but in opposite directions and the differential will not rotate. We know then that the mill motor is making revolution for revolution at the speed required. If this mill motor does not operate at its correct speed the differential will start to rotate which will

cause the regulator to adjust the field of the D.C. motor to be controlled and bring it back to its proper speed.

Regardless of the inherent regulation of direct current motor or the type of external regulator on the motor used, the instant load is put on the motor there will be a slight drop in speed which will be recovered in time, depending upon the magnetic characteristics of the machine. If the armature has a relatively high flywheel effect the momentary drop will not be great but appreciable time will be required for the motor to recover its speed. On the other hand if the flywheel effect is small there will be a greater drop in speed but the recovery will be accomplished in a shorter time. The type of regulator as described by Mr. Kenyon will shorten this time of recovery over that obtained without an external regulator.

The motor controlled will not lose speed in revolutions but will merely lag back as a synchronous motor does while it is carrying load. This might be more clearly explained if we assume two men walking side by side. If for some reason pressure were placed against the progress one man was making he might momentarily lag by half a step but continue to walk at the same speed as the other man. When this pressure is relieved it could be assumed he would advance this half step and again be in parallel with the other man. This is approximately what the direct current motor does.

An external regulator will find its best use on mills where the delivery speed of the metal is high. The difficulty of avoiding cobbles is greater where the operators are required to roll the metal at an extreme speed.

Another feature which should be weighed when an external regulator is being given consideration is the length of the metal finished. If the product finished is reasonably short any error cannot accumulate to a great value, but if the product is rolled to any great length an accumulating error may become serious.

Structural Changes in Hypo-Eutectoid Steels on Heating*

By SIR H. C. H. CARPENTER, F. R. S., and J. M. ROBERTSON, D. Sc.,
London, England.

This paper deals with the solution of ferrite on heating and the effect of initial temperature on the structure obtained on cooling.

During heating, ferrite is absorbed by the spread of austenite from the points originally occupied by pearlite. When heating is continuous this results in the formation of a carbon gradient, which may affect the structures obtained on cooling from temperatures within the critical range. The experiments show, however, that this gradient has little effect on the structure obtained on cooling after 15 min. at the initial temperature.

From each point at which the formation of austenite begins, an area of austenite spreads outwards into the ferrite, and on quenching this area is retained as martensite. This continuous area consists however, of many small grains, and during slow cooling the formation of ferrite begins at the boundaries of these. Thus, from comparatively large areas of austenite small-grained ferrite-pearlite structures are obtained. During moderately rapid heating the spread of austenite tends to some extent to follow the boundaries of the ferrite grains, and Whiteley has shown that this tendency becomes more pronounced as the rate of heating is decreased.

Just above the upper limit of the critical range steel consists of a system of small austenite crystals. As the temperature is raised, some of these begin to grow and absorb those around them. As the temperature is further raised, the number of growing crystals and the rate of growth increase. Finally all the small crystals are absorbed, and grain-growth practically stops. For a given steel there are two fairly well defined grain-sizes: (1) That formed when it is heated just above the critical range, and (2) that formed when it is heated to high temperatures. When the steel is in either of these conditions the grain-size does not appreciably increase with the time of heating. At intermediate temperatures it consists of a mixture of large and small grains, and the large grains continue to grow with time.

With a given rate of cooling, more ferrite is formed from small-grained than from large-grained austenite. The grain-size influences the amount of ferrite, because ferrite begins to form at the grain boundaries, whose number decreases as the grain-size increases.

All steels containing between 0.2 and 0.6 per cent. of carbon behave in much the same way during heating, but steels with more or less than this amount behave rather differently. In steel containing 0.1 per cent of carbon, small austenite grains are produced by heating just above the critical range, but small ferrite crystals are not obtained on cooling. In fact, in steel of this composition the size of the ferrite crystals is not affected by the initial temperature but only by the rate of cooling. This is partly due to the coalescence of ferrite during cooling. In this same steel, however, the size and distribution of the pearlite grains are influenced to a marked extent by the initial temperature for each austenite grain gives rise to a pearlite grain. Thus, when cooled from within the critical range the pearlite occurs as groups of small particles, when cooled from just above the range the particles are widely distributed, and as the initial temperature is raised above this,

*Abstract of paper presented before the British Iron and Steel Institute, May, 1933.

their size increases in accordance with the size of the austenite grains.

When steels of nearly eutectoid composition are heated into or just above the critical range, their behaviour is influenced by the fact that the solution of the excess ferrite is completed at about the same temperature as that of the cementite in the pearlite. Over a certain range of temperature, therefore, these two constituents act as nuclei for the initiation of the change on cooling. The structure thus produced consists of a very intimate mixture of ferrite and pearlite. The typical structure consisting of definite grains of pearlite surrounded by envelopes of ferrite is not obtained until the steel is heated to a high enough temperature to dissolve all the ferrite and cementite and produce homogeneous austenite.

The formation of the banded structure is affected by the initial temperature as well as by the rate of cooling. The higher the initial temperature and the longer the time of heating the more slowly must the steel be cooled in order to obtain bands.

Repeated heating to a temperature just above the critical range does not produce a progressive decrease in grain-size. Starting with large grains, one heating just above the critical range produces marked refinement, but repetition of this treatment produces only a very small change.

Arc Welding of Stainless Steels

By E. A. HURME
Clark Controller Co., Cleveland, Ohio

EDITOR'S NOTE:—The use of stainless alloys, in the fabrication of containers for the chemical, oil, dairy and other industries demanding materials to withstand excessive heat and corrosion, is increasing rapidly and will increase still faster when fabricators learn that it can be welded successfully, particularly in the thin sheets. The stainless alloys, because of their extra-ordinary characteristics have presented a complex set of fabrication difficulties of which welding has been an important one.

Many of the manufacturers, who have been called upon to recommend suitable welding rods for stainless alloys, have been hampered by lack of accurate basic information which would enable them to select and specify intelligently the particular type of stainless rod best suited to given requirements.

In compiling the information contained in this write-up, the author has endeavored to cover some of the general characteristics of the parent metals as well as points on proper welding technique required.

The increasing use of inaccurately called "stainless" steels is a matter of common knowledge. There is considerable variety in the types of stainless now being produced, but a survey of these types shows that the more popular analyses may be grouped into some five classes according to Table 1.

All of these alloys are very resistant to the attack of all acids except Sulfuric and Hydrochloric and to oxidation or scaling at high temperatures. Their various properties, either singly or in combination, make possible their use in applications where no other material can serve nearly as well.

TABLE I

Class	Chromium	Nickel	Carbon	Manganese	Silicon	Sulfur	Phosphor
A	17-19	8-10	.07 Max.	.50 Max.	.50 Max.	.03 Max.	.03 Max.
B	22-26	12-14	.20 "	2.00 "	.75 "	.03 "	.03 "
C	12-14	.25 Max.	.10 "	.50 "	.50 "	.03 "	.03 "
D	16-18	.25 "	.10 "	.50 "	.50 "	.03 "	.03 "
E	25-30	.25 "	.10 "	.50 "	.50 "	.03 "	.03 "

Classes A and B are known as chrome-nickel stainless steels. Classes C, D and E are called straight-chrome stainless steels. The stainless steels differ from low carbon steels in that they have:

(1) Much greater resistance to corrosion.
(2) Much greater resistance against scaling at high temperatures.
(3) Considerably greater strength at both low and high temperatures.
(4) Co-efficient of linear expansion 50% greater than that of carbon steel. (This statement applies only to the chrome-nickel stainless steels).
(5) Heat conductivity 1/3 to 1/2 that of low carbon steel.
(6) Higher electrical resistance.
(7) Lower melting point.

Alloys of class A (as shown in the table) are probably the most widely used in the stainless field; they are generally called the "18-8" type, the figures referring to the chromium and nickel contents. "18-8" is used where maximum resistance to corrosion and permanent beauty of surface are desired as in hotel, restaurant, dairy, farm, brewery, cannery and laundry equipments. This alloy is also finding numerous architectural applications; it was used, for instance, for exterior trim on the Empire State and Chrysler Buildings in New York and the La Salle-Wacker Building in Chicago. It has also been extensively used for interior trim.

Alloys of class B have great resistance to high temperatures plus high strength. They resist temperatures up to about 2100 degrees F. and are used

for furnace and steam engine parts, carbonizing boxes and pots, boiler baffles, firebox sheets, etc.

Alloys of classes C and D are corrosion resistant and somewhat responsive to heat treatment. They are used where resistance to chemical and atmospheric corrosion is desired and where surface discoloration is not objectionable. They will resist temperatures up to 1600 degrees F. and find their application in nitric acid equipment, steam engine parts, pyrometer protection tubes, tanks, chemical equipment, etc.

Alloys of Class E are used where maximum heat resistance is desired but where no difficult fabrication is involved. They resist temperatures up to 2150 degrees F. and are used in furnace parts, boiler baffles, carbonizing boxes, etc.

A survey of the manifold applications of stainless alloys shows that they find extensive use in the food industry, the petroleum industry, the automotive industry, the chemical industry, high temperature and pressure equipment, marine equipment, the architectural field, the railway field, the aircraft industry, the dyeing industry, the brewing industry and many miscellaneous fields too numerous to record here.

With regard to the selection of alloys for various applications, the user should always be guided by the steel mill's recommendations. The subjects of corrosion and heat resistance are complicated and involve many factors. The steel mills which market the alloys have made numerous tests of the various stainless steels and are able definitely to recommend the most suitable alloy for any particular application.

The metallography of the stainless steels is a rather complex subject, therefore no attempt will be made to discuss it here. Only the notorious "intergranular corrosion" to which 18-8 is sometimes susceptible will be briefly explained. 18-8 retains an austenitic structure even during slow cooling, but if the temperature of the cooling alloy lingers in the range of 1500-1000 degrees F. there occurs a precipitation of iron and chromium carbides from the austenitic solid solution. This precipitation causes the "intergranular susceptibility" which generally reduces the intergranular corrosion resistance of the metal. If the carbon content is held below 0.07% there is not so much carbide and what little there is has a greater tendency to remain in solution. Certain "inhibitors," such as titanium, if present in the alloy, can be made to eliminate harmful carbide precipitation. Harmful precipitated carbides are redissolved by heating to 1650 degrees F. and are retained in solution by rapid cooling from that temperature. Thus a carbon content below .07%, the presence of an "inhibitor," or a heat treatment will practically eliminate the possibility of intergranular corrosion.

In this connection it should be noted that any susceptibility to intergranular corrosion developed during the arc welding operation will be located mostly in the parent metal. This is because the weld metal cools too rapidly to permit carbide separation, while on the other hand the parent metal, which, of course, extracts the heat from the weld, cools rather slowly. It will be seen that the weld, unless put in service in the range 1500-1000 degrees F. will not corrode as a result of intergranular susceptibility.

The steel mills are now marketing the so-called "stabilized" stainless steels. These steels contain an "inhibitor" (generally titanium) and if they are properly made they are immune from intergranular corrosion. This "stabilized" parent metal is especially suitable for arc welding fabrications. However, it is evident from the discussion above that "stabilized" weld metal is generally unnecessary and will only increase the price of welding without effecting any beneficial results. High grade stainless steel welding rods with the proper amount of titanium for "stabilizing" are available for applications where the weld must withstand corrosion either after or during exposure to temperatures of 1500-1000 degrees F.

2. The Welding Operations.

From the welding standpoint all the stainless steels may be divided into two general groups, namely: (1) those containing chromium and nickel in various proportions and (2) those containing only chromium regardless of the amount. These two groups possess in some cases similar welding properties and in other cases different welding properties, as indicated in Table II.

TABLE II

Group I—Chrome Nickel Steels

(a) Welds are soft and ductile whether cooled slowly or rapidly.
(b) Non-Magnetic.
(c) Co-efficient of expansion 50% greater than that of steel. More distortion in welding than with steel.
(d) Silky weld fracture.
(e) Low heat conductivity (1/3 to 1/2 that of steel).
(f) High electrical resistance.
(g) Fusing characteristics excellent in welding.

Group II—Straight Chrome Steels

(a) Weld metal generally air hardening. Weld is brittle and will withstand practically no distortion at room temperature. No heat treatment will overcome this brittleness.
(b) Magnetic.
(c) Co-efficient of expansion somewhat less than that of steel. Not so much distortion in welding.
(d) Coarse weld fracture.
(e) Low heat conductivity.
(f) High electrical resistance.
(g) Fusing characteristics excellent in welding.

The chrome-nickel stainless steels (Group I) adapt themselves very well to arc welding, highly successful welds having been made on sheets as thin as 26 gauge. The welds are soft, machinable, and very ductile and can be bent back onto themselves without cracking. The tendency for warpage during or after welding is greater in the case of steels of this group than in the case of plain low carbon steels. For this reason care must be taken in design to limit warpage and proper allowances should be made to counteract any which will occur. The use of jigs for light work is quite necessary. Preheating to 300 degrees—400 degrees F. is desirable on certain rigid jobs in order to prevent distortion during the welding operation. Preheating allows the weld and the parent metal to cool down and contract together.

Welds made with straight chrome stainless steels

(Group II) are generally hard and brittle and will show practically no bend at room temperature. If, however, the welds are in service at a temperature of 200 degrees F. or more, they will be more ductile and at 400 degrees F. or 500 degrees F., they will stand considerable bending before fracture. The brittleness at room temperatures results partly from the rapid grain growth of these alloys when heated to a high temperature during the welding process and partly from their air hardening characteristics.

An arc welded fabrication of straight chrome stainless steel is most suitable in applications where the working temperatures are around 400 degrees to 500 degrees F. and where a minimum amount of movement due to expansion and contraction is necessary, as in locomotive fire boxes.

Generally speaking, a welding rod of the same analysis as the parent metal should be used in order to give a homogeneous product. However, if welds are to be made on straight chrome steel where no provision for contraction is possible it becomes necessary for the weld to possess substantial ductility in order to withstand the strain. The proper procedure in such cases is to use a chrome nickel stainless rod.

In actually making the weld, certain precautions have been found to be desirable. These apply to the metallic arc welding of all types of stainless steels. In most cases it is best to make the welding rod the positive pole (reversed polarity). Excessive puddling and retracing should be avoided. The size of the electrode should be as small as possible in view of the thickness of stock. The welding current should be only enough to maintain a short stable arc, since low currents greatly reduce the likelihood of oxidation loss, excessive grain growth, weld porosity, undercutting, carbide precipitation, and related evils. Grease, oxide, scale and dirt, unless thoroughly removed before and after the welding operation, will impair the corrosion resistance of the joint.

In cleaning, the slag should be first cracked off with a chisel or similar sharp tool. The surface of the bead and the nearby parent metal should next be cleaned by means of a wire brush. Better results are obtained if the surface is buffed with a motor-driven brush. In cases where extreme corrosive attack is to be encountered the weld area should be thoroughly pickled, or "passivated," or both. Recommendations with regard to pickling or "passivating" solutions may be obtained from the steel makers.

In instances where a perfect color match between a ground and polished weld and the parent metal is desired, it is best to anneal the complete article after welding. The use of thoroughly annealed stock is often equally effective in the case of the chrome-nickel stainless alloys. It appears that the color match is best when the hardness of the stock is the same as that of the weld.

3. Electrodes for Arc Welding Stainless Steels.

Electrodes for the metal arc welding of stainless steels must have a flux coating. If a bare rod is used the resulting weld is almost always of a spongy, porous nature and is quite useless, regardless of the requirements. The function of the flux coating is to stabilize the arc and to protect the metal from oxidation or contamination as it passes through the arc and solidifies. One of the true measures of a stainless electrode is how well the coating performs its function.

The weld metal deposited by a good stainless steel electrode should have:

(1) Complete freedom from porosity and blowholes.
(2) Mechanical properties approximating those of the parent metal.
(3) Corrosion resistance equal to that of the parent metal.
(4) Machinability comparable with that of the parent metal.

Weld metals deposited by high grade rods are chemically correct. The chromium and nickel contents do not decrease materially in passing through the arc, while the carbon content remains practically constant. Pads of four or more layers may be very successfully built up and the deposits will be free from pores and slag inclusions.

If the ends of two ¼" plates of 18-8 are joined by a double-vee butt weld made with high grade 18-8 base welding rod, the weld, with all re-enforcement removed, will develop a strength equal to about 90% that of the parent metal. On lighter material where a single pass weld is sufficient, the weld will develop strength of a somewhat higher order. If a bead is deposited with this type of rod on ¼" parent metal and if the parent metal is bent away from the bead, the per cent elongation in the outer fibres of the weld metal will exceed 60% in ½" gauge length.

The essential requirements of a stainless steel welding rod are that the weld metal must be dense and free from slag inclusions, that the proper chemical composition must be retained during passage through the arc and that the rod must operate at low currents with a stable arc, little spatter and a minimum of undercutting. All of these requirements are fully met in high grade stainless steel rods. Usually strength of the weld is of minor importance, since where strength is required standard practice dictates the use of substantial re-enforcement. With proper welding technique, a good rod and correct re-enforcement, the possibility of weld failure is remote.

Considerable commercial use is now being made of a recently developed product known variously as "stainless clad," "bi-clad," "tri-clad," "plykrome," etc. This product consists of a fairly thick layer of mild steel covered on either one or both sides with a thin veneer layer of stainless steel, generally 18-8. The advantage of this is that the buyer can have the protection afforded by stainless without paying the high price he would have to pay if the metal were all stainless.

Arc welding plays an integral part in the original production of "stainless clad." A slab of stainless is laid on top of a slab of mild steel and an edge weld joining the two pieces is made. This weld encircles the entire composite slab and provides an air tight joint. The piece made in this way is heated to a rolling temperature and is rolled down to the various sizes marketed. During the rolling process a pressure weld is developed between the contracting surfaces of the stainless and mild steel. It is of interest to note that stainless electrodes are used in making the edge weld previously referred to.

As would be expected, the fabrication of these

"clad" steels is something of a problem. In making a butt weld between two clad steels, stainless steel side should be welded with a stainless steel rod and a good quality mild carbon steel deposited on the mild carbon side, unless the plates are thin, in which case full penetration may be secured in the stainless weld. The difficulty of making a satisfactory weld is in the fact that enough weld metal must be deposited to provide a substantially strong joint and the weld must be made in such a way that stainless and low carbon steels are not fused together to any appreciable extent. If they are fused together, the result is that the stainless becomes diluted and consequently less resistant to corrosion. Insofar as possible, melting must be avoided at or near the junction point of the two kinds of metal.

Tests made indicate that the best results are obtained when so welded that there will be no actual fusion of the two kinds of welds. Penetration of each weld being just a little less than the thickness of the metal. Joints made this way will have satisfactory strength because of the weld re-enforcement. A weld of this type is undeniably ticklish, requiring careful manipulation and strict current control.

The order in which the welds are made seems to have little effect on the final result. It seems best however, to make the low carbon weld first.

The Future of Industry Under The National Recovery Act

(Continued from page III)

group and the President's Administrators of the Recovery Act. These agreements can be changed and improved upon as may be mutually agreed as the plan proceeds.

Organized labor has a very large influence in this new administrative group and if Labor meets this new opportunity and its accompanying responsibility in a constructive way, it is bound to have every possible consideration.

It is generally conceded that a larger and better distributed buying power is essential to more permanently prosperous conditions; and it can be assumed that industry and business of every character will be willing and anxious to improve working conditions just as fast as progress can safely be made.

It is all too often forgotten that when industry invests its capital in land, buildings, machinery and equipment, that capital is so definitely and permanently invested, that it can only pay wages and salaries out of the price received for its products and the service it renders its clients.

Our future price structures must therefore be based upon such a proper relation between fixed costs, wages, salaries and returns to capital invested, that each of these factors will be fully protected and conditions created that will not only be fair to all, but that will more nearly insure permanent operation and profitable employment.

ITEMS OF INTEREST

PERSONNEL CHANGES

The Poole Foundry and Machine Company, Baltimore, Md., announce the appointment of the McVoy-Hausman Company, Brown-Marx Building, Birmingham, as their representatives in the State of Alabama for the sale of Poole Flexible Couplings.

▲

The Delta-Star Electric Company, Chicago, Ill., announce the appoint of Harrington & Company as their representatives in the New York State territory with headquarters at 1796 Main street, Buffalo, N. Y.

▲

Mr. Frank J. Wood returned from Leningrad, U. S. S. R., on the S. S. Bremen June 7. For the past year he was associated with the Freyn Engineering Company as Rolling Mill Consultant at their Leningrad headquarters. Mr. Wood is a member of the Association of Iron and Steel Electrical Engineers and also of the Engineers' Society of Western Pennsylvania.

Mr. R. B. Wilson, sales manager of the St. Louis plant of Joseph T. Ryerson & Son, Inc., has been made manager of the St. Louis plant of that company.

ASSOCIATION NOTES

The Pittsburgh District Section of the A. I. & S. E. E. will hold a Mid-Summer Golf Tournament and "Get-Together," July 25, 1933, at the St. Clair Country Club. D. I. Bohn is general chairman and he has selected the following committeemen: Messrs. A. C. Dyer, B. J. Ballard, A. D. Adams, W. E. Miller, T. Simpers, J. Bryan, V. J. Nolan, G. L. Stout, C. Ostrum, T. Towle, J. M. Kelly, R. E. Brown, W. Wray, J. R. Lewis, J. L. Young, J. J. Bangert, G. E. Stimple, R. E. Lewis, E. L. Upp, J. W. Bates, J. I. Kaspari, W. B. Shirk and E. S. Stickle. To get to the St. Clair Country Club go through the Liberty Tubes and continue out West Liberty avenue and Washington road to Clifton, turning right off Washington road at this point. Play starts at 12:30 p. m.

STATISTICS OF THE IRON AND STEEL INDUSTRY

Each month there will appear in the Iron & Steel Engineer statistics in connection with the Iron and Steel Industry. This information and data will be especially valuable to manufacturing firms servicing the Iron and Steel Industry.

Following is data and information in connection with Coke Blast Furnaces in the United States:

TABLE 1

State	Operating Companies	Plants	Stacks	Annual Pig Iron Capacity	Stoves
Alabama	7	11	25	3,375,000	114
Colorado	1	1	5	540,000	20
Illinois	5	6	25	5,349,000	98
Indiana	3	3	18	4,968,000	69
Kentucky	1	1	1	144,000	5
Maryland	1	1	6	1,479,600	24
Massachusetts	1	1	1	165,000	3
Michigan	2	2	4	725,000	16
Minnesota	2	2	3	447,500	14
Missouri	1	1	1	125,000	4
New York	8	9	21	4,130,500	95
Ohio	19	29	58	11,889,500	234
Pennsylvania	23	35	93	17,544,250	384
Tennessee	4	6	7	315,700	29
Utah	1	1	1	175,000	4
Virginia	4	5	5	325,000	24
West Virginia	1	1	2	550,000	7
Totals	84	115	276	52,248,050	1,144

TABLE 2

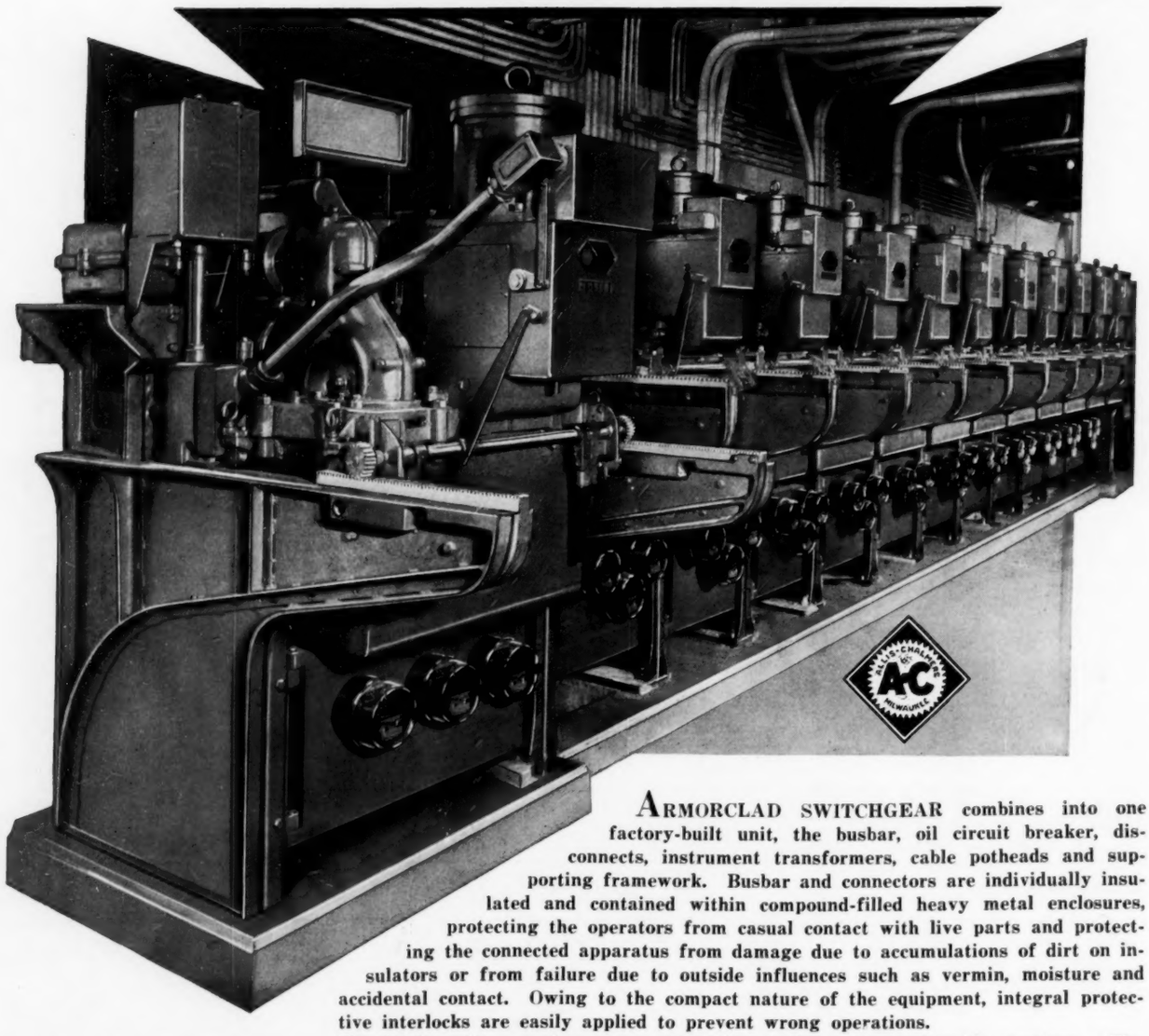
State	Operating Companies	Plants	Boilers*	Total Boiler H.P.*	Turbo Blowers*	Blowing Engines*	Pig Casters
Alabama	7	11	184	90,630	9	77	7
Colorado	1	1	29	19,400	4	3	2
Illinois	5	6	152	69,757	10	43	12
Indiana	3	3	57	32,756	8	25	9
Kentucky	1	1	7	2,700	.....	3	.....
Maryland	1	1	27	24,873	2	16	1
Massachusetts	1	1	6	800	2	.....	1
Michigan	2	2	15	4,776	3	5	2
Minnesota	2	2	8	3,200	1	9	2
Missouri	1	1	4	2,000	.....	2	1
New York	8	9	253	76,579	8	53	10
Ohio	19	29	352	218,527	26	100	40
Pennsylvania	23	35	745	350,467	28	211	55
Tennessee	4	6	42	9,450	.....	19	1
Utah	1	1	6	3,702	2	.....	1
Virginia	4	5	47	11,992	3	10	1
West Virginia	1	1	25	14,900	2	5	2
Totals	84	115	1,959	936,509	108	581	147

* Number reported.

TABLE 3

State	Operating Companies	Plants	Sinter Plants	Plants Capacity (Tons)	Slag Pits	Plants Capacity (Tons)
Alabama	7	11	.....	.....	1	.....
Colorado	1	1	1	100,000	.....	.....
Illinois	5	6	3	153,000	5	1,010,000
Indiana	3	3	3	299,000	7	1,465,000
Kentucky	1	1	1	15,000	.....	.....
Maryland	1	1	.....	.....	1	90,000
Massachusetts	1	1	.....	.....	.....	.....
Michigan	2	2	2	30,000	2	180,000
Minnesota	2	2	.....	.....	5	225,000
Missouri	1	1	.....	.....	.....	.....
New York	8	9	4	1,131,000	.....	.....
Ohio	19	29	16	1,224,350	15	1,439,000
Pennsylvania	23	35	16	2,789,400	32	2,424,000
Tennessee	4	6	1	54,750	.....	.....
Utah	1	1	.....	.....	.....	.....
Virginia	4	5	3	220,000	1	15,000
West Virginia	1	1	1	72,000	2	260,000
Totals	84	115	51	6,088,500	71	7,108,000

ARMORCLAD TO PROTECT LIFE AND PROPERTY



ARMORCLAD SWITCHGEAR combines into one factory-built unit, the busbar, oil circuit breaker, disconnects, instrument transformers, cable potheads and supporting framework. Busbar and connectors are individually insulated and contained within compound-filled heavy metal enclosures, protecting the operators from casual contact with live parts and protecting the connected apparatus from damage due to accumulations of dirt on insulators or from failure due to outside influences such as vermin, moisture and accidental contact. Owing to the compact nature of the equipment, integral protective interlocks are easily applied to prevent wrong operations.

The basic unit comprises two parts, the stationary and movable portions. The movable portion consists of the circuit breaker equipment, and on the indoor type is supported on horizontal frame standards and conveniently racked in and out of the stationary portion to open and close disconnects. Units are available in all standard ratings for metal-clad switchgear.

Products for the Steel Mill

Main Roll Drives
General Purpose and Special Motors
Motor Generators
Switchboards—Transformers
Armorclad Switchgear
Mercury Arc Rectifiers
Steam Turbine Units
Steam Engines—Condensers
Blast Furnace Gas Engines
Blowing Engines
Centrifugal Blowers
Rotary Compressors
Texrope V-Belt Drives

ALLIS-CHALMERS

REYROLLE SWITCHGEAR